NASA/CR–2020-220589/Appendices/Volume II

Quiet Supersonic Flights 2018 (QSF18) Test: Galveston, Texas Risk Reduction for Future Community Testing with a Low-Boom Flight Demonstration Vehicle

Juliet A. Page
Volpe National Transportation Systems Center, Cambridge, Massachusetts

Kathleen K. Hodgdon
Penn State University, State College, Pennsylvania

Robert P. Hunte and Dwight E. Davis
Applied Physical Sciences Corporation, Groton, Connecticutt

Trent A. Gaugler
Gaugler Consulting, Easton, Pennsylvania

Robert Downs
Volpe National Transportation Systems Center, Cambridge, Massachusetts

Robert A. Cowart
Gulfstream Aerospace, Savannah, Georgia

Domenic J. Maglieri
Eagle Aeronautics, Newport News, Virginia

Christopher Hobbs
KBRWyle, Arlington, Virginia

Gary Baker
Volpe National Transportation Systems Center, Cambridge, Massachusetts

Matthew Collmar
Gulfstream Aerospace, Savannah, Georgia

Kevin A. Bradley
KBRWyle, Arlington, Virginia

Brian Sonak and Diana Crom
Penn State University, State College, Pennsylvania

Christopher Cutler
Volpe National Transportation Systems Center, Cambridge, Massachusetts

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National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23681-2199

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Technical Monitor: Jonathan Rathsam, NASA Langley Research Center

Point of Contact: Larry J. Cliatt, II, NASA Armstrong Flight Research Center

Available from:

NASA STI Program/Mail Stop 148
NASA Langley Research Center
Hampton, Virginia 23681-2199
Fax: 757-864-6500

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Acronyms

Abbreviation	Term
ABS	Address Based Sample
ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
ARMD	Aeronautics Research Mission Directorate
ATM	Automatic Transaction Machine
CAEP	Committee on Aviation Environmental Protection
CDMA	Code division multiple access
CDNL	C-weighted Day-Night Noise Exposure Level
COAMPS	Coupled Oceanographic Atmospheric Mesoscale Prediction System
COAMPS OS	Coupled Oceanographic Atmospheric Mesoscale Prediction System On Scene
dBA	A-weighted Decibels
dBC	C-weighted Decibels
DNL	Day-Night Noise Exposure Level
EAFB	Edwards Air Force Base
EDA	Exploratory Data Analysis
FAA	Federal Aviation Administration
GSM	Global System for Mobile Communications
ICAO	International Civil Aviation Organization
LBDM	Low Boom Dive Maneuver
LBFD	Low Boom Flight Demonstrator
LLZd	Zwicker loudness levels in phons, for diffuse incidence, calculated using a time constant of 70 msec and averaging across the two peaks.
LLZf	Zwicker loudness levels in phons, for frontal incidence, calculated using a time constant of 70 msec and averaging across the two peaks.
MAC	Media Access Control
METARS	World Meteorological Organization surface weather reporting format
NQ	FAA Noise Quest website hosted by Pennsylvania State University (http://www.noisequest.psu.edu/)
PL	Perceived Level (dB)
PNL	Perceived Noise Level (dB)
SERDP	Strategic Environmental Research and Development Program
SIGMETS	Significant Meteorological Event reporting format
SIM	Subscriber Identity Module
SMM	Social Media Monitoring
TAF	Terminal Aerodrome Forecast

Abbreviation	Term
TCPA	Telephone Consumer Protection Act
USPS	United States Postal Service
VPN	Virtual Private Network
WSPR	Waveforms and Sonic Boom Perception and Response
ZDNL	Z weighted Day-Night Sound Level

Foreword/Preface

For nearly 70 years, man has flown faster than the speed of sound. Concorde, the only successful commercial operation, provided the public with supersonic travel at Mach 2+ but only over a limited number of routes due to its objectionable sonic boom. Retired in 2003, Concorde went down in the history books as a technological marvel well ahead of its time. Unfortunately, no civilian operational replacement has emerged. But that might be changing, thanks to the relentless pursuit of industry, NASA, and a small group of sonic boom experts.

NASA's Aeronautics Research Mission Directorate (ARMD) has identified a near term (2015-25) strategic goal of enabling the establishment of a standard for acceptable overland supersonic flight, in cooperation with international standards organizations. ARMD has indicated that it will develop and validate analysis tools and technologies intended to enable the design and development of supersonic aircraft with low sonic boom [NASA, 2015]. In the longer term (2025-35), ARMD will continue research on technologies required to meet the desired boom level in larger aircraft, and will also conduct research in areas related to other challenges to successful supersonic transports. This research will include the development and validation of technologies and tools to reduce propulsion emissions and noise affecting the airport community.

In 2015 NASA awarded a Community Response NASA Research Announcement (NRA) to Applied Physical Sciences (APS) for conceptualizing a sonic boom community response test in anticipation of a low-boom flight research program. Now here in early 2016, NASA Administrator Charles Bolden announced a $20M award over seventeen months to a US contractor to further develop a low-boom experimental aircraft toward its next milestone, a preliminary design review. NASA's actions are providing core leadership that will make it possible to realize quiet civilian supersonic flight over land. Such flight is currently banned in the United States and elsewhere. Changing the current regulations in the US and abroad will require extensive measurements showing that the advancements in sonic boom signature shaping technology are sufficient to find community acceptance. If these NASA programs are successfully executed, data acquired from the flight program will be used to guide policy on international standards for sonic boom.

Imagine a future where you could board a quiet supersonic transport aircraft and make a day trip between continents separated by oceans. With today's computational horsepower and analytical software tools coupled with the ingenuity of the human mind and passion to solve the world's most challenging problems, engineers and researchers are about to 'crack-the-code' to enable the development of these aircraft.

Fasten your seat belts … we're about to go supersonic!

Executive Summary

The Applied Physical Sciences (APS) lead team consisting of Penn State University Applied Research Laboratory, Penn State Survey Research Center, Volpe National Transportation Systems Center, Gulfstream Aerospace, Wyle Laboratories, Eagle Aeronautics and Gaugler Consulting has been tasked with developing a conceptual plan for future testing of the NASA Low-Boom Flight Demonstrator (LBFD). The objectives of the Community Response NRA Phase 1 are:

(1) Create a conceptual sonic boom community test within the contiguous United States,
(2) Identify key risks and development areas associated with the planning, execution, and data analyses of such testing, and
(3) Propose risk reduction activities in priority research areas that require further understanding prior to executing this test.

NASA, in combination with a few of our team members, conducted a proof-of-principle pilot test in 2011 using an F18 low boom dive maneuver (LBDM) over Edwards Air Force Base (EAFB) to demonstrate techniques for gathering human subjective response to low booms. This research project, affectionately referred to as WSPR [Page, 2013], was a practice session for future low boom testing over non-acclimated communities using the purpose-build low boom research aircraft mentioned above. Key WSPR outcomes include: confidence in survey instrumentation, modes of delivery, data acquisition and dose-response correlation, and subsequent statistical analyses procedures.

Building from our team's WSPR experience, this document describes a conceptual dose-response test plan to address the following activities: recruitment, outreach, subject survey collection, correlation to noise, and statistical analyses. Non-acclimated community testing will introduce many challenges not encountered at EAFB, e.g. off-range focus/climb signature placement, undefined participant mobility, wide area objective measurement, and diverse community dynamics. Herein we provide the basis for a low-amplitude sonic boom subjective noise test in six different regions in the United States that will ultimately allow international regulatory agencies to select the metrics necessary to support international policy allowing for the certification of civilian supersonic overland flight. This document presents our team's perspective on risk identification, prioritization and mitigation. We have developed a risk reduction plan and identified key risk mitigation activities and outcomes along with proposed Phase 2 activities for further exploration and mitigation of high priority risks.

1. Introduction

1.1 Background

In 2011 NASA funded the Waveforms and Sonic Boom Perception and Response (WSPR): Low-Boom Community Response Program Pilot Test [Page *et al.,* 2013]. This test was conducted over Edwards Air Force Base in California in 2011 and was designed to test and demonstrate techniques to gather data relating human subjective response to multiple low amplitude sonic booms. It was in essence a practice session for further wider scale testing on non-acclimated communities using a purpose built low-boom demonstration aircraft. Non-acclimated communities present additional challenges beyond those overcome during the WSPR experiment. These include: the absence of a predisposition to aircraft noise; willingness to participate in the experiment; safety and security, and a host of other issues that present risks to the success of the experiment and the attainment of certification for supersonic overland flight.

The WSPR test was designed by members of this current project team and was executed in conjunction with NASA. The WSPR program addressed the following: design and development of an experiment to expose people to low-amplitude sonic booms, development and implementation of methods for collecting acoustical measures of the sonic booms in the neighborhoods where people live, design and administration of social surveys to measure people's reactions to sonic booms, and an assessment of the effectiveness of various elements of the experimental design and execution to inform future wider-scale testing. Key outcomes from that test were the confidence in our survey instrumentation, modes of delivery, data acquisition and dose-response correlation and subsequent statistical analyses procedures.

Building on the success of WSPR our team has adopted WSPR Risk Reduction (WSPRRR) as the name for this effort. This document presents a conceptual plan for a community response test of a low boom flight demonstrator experimental aircraft, identification and prioritization of the risks associated with a test of the community response to a Low Boom Flight Demonstrator experimental aircraft and the definition of Phase 2 activities to mitigate these risks.

1.2 LBFD Test Design

One of the key elements of a future LBFD sonic boom dose-response test design is ensuring adequate representation of the US general population. Studies have been conducted [Rachami & Page, 2010; Salamone, 2009] to project future sonic boom noise exposure in the US (Figure 1-1) and indicate on the order of 10 daily booms maximum in certain regions of the country. A quote attributed to a team member and highlighted at the project kickoff meeting was: "If we expect booms to be delivered at a certain noise level, at certain intervals, etc., then that's exactly how we need to design the study. Then we'll get results that we can extrapolate for use in changing regulatory policy." Our test plan has detailed in the following Sections and captures this mindset in both our regional approach for testing and the planned dose delivery. We leverage the prior WSPR test materials and strategy as appropriate. A general testing template and design process was developed then adapted in terms of detailed site selection and flight track planning for each proposed locality.

We embarked on a spiral design process (Figure 1-2) with expert team members in the various disciplines leading a rotation of topics. We conducted brain storming sessions to develop ideas and then transitioned to a focusing process whereby we assessed the practicality, risks and synergies of the concepts and began the test design refinement process – which is still ongoing.

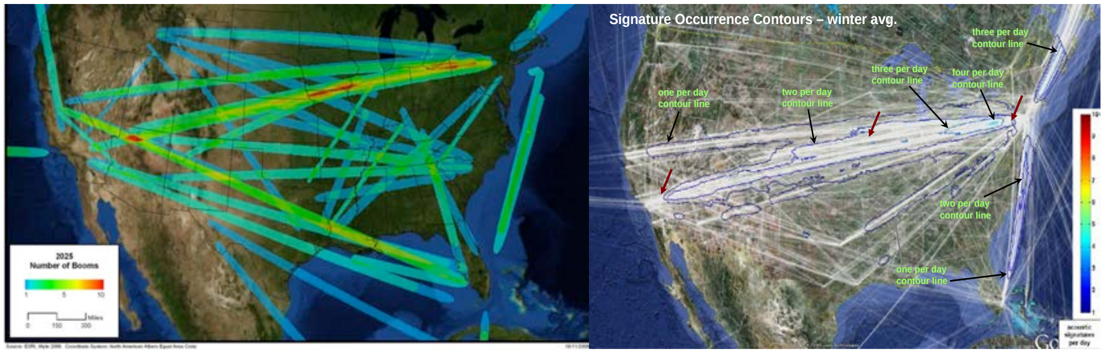


Figure 1-1 Projected US Sonic Boom Exposure from Two Studies

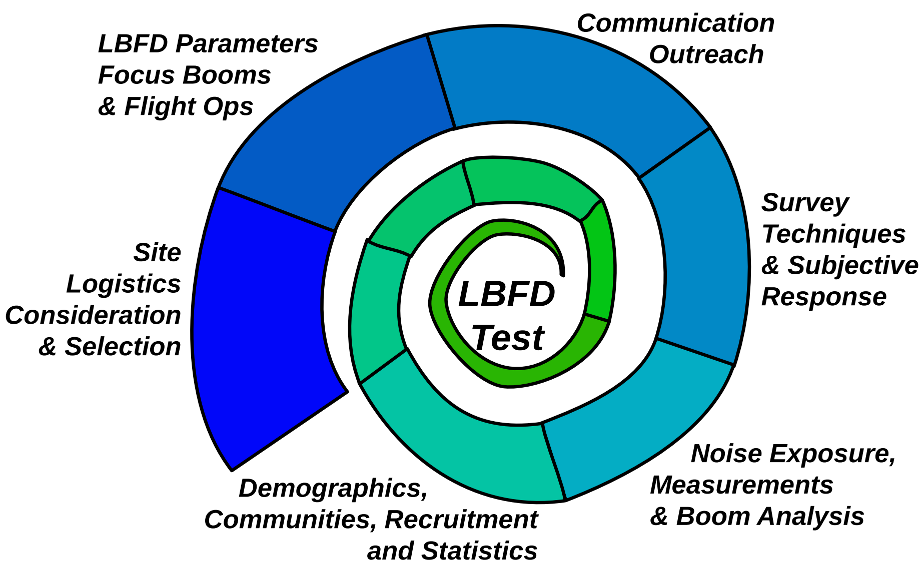


Figure 1-2 Spiral Design Process

1.3 LBFD Test Risk Identification

Central to our spiral design process was the identification of risks. We developed and maintained a comprehensive risk chart and determined (with much discussion) probability of occurrence and consequence of occurrence. This numerically led to a prioritization of our identified risks as presented in Figure 1-3 and detailed in Section 10 Risk Identification and Mitigation Strategies.

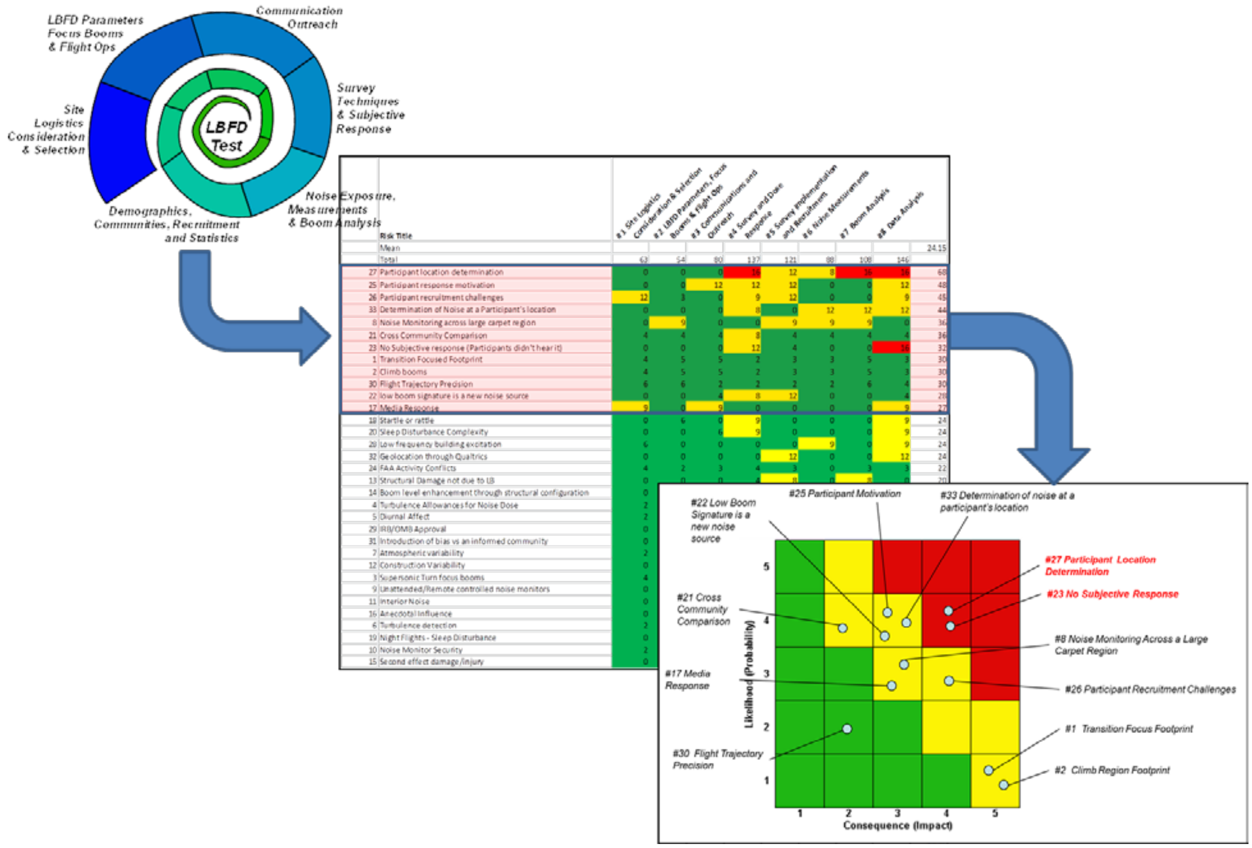
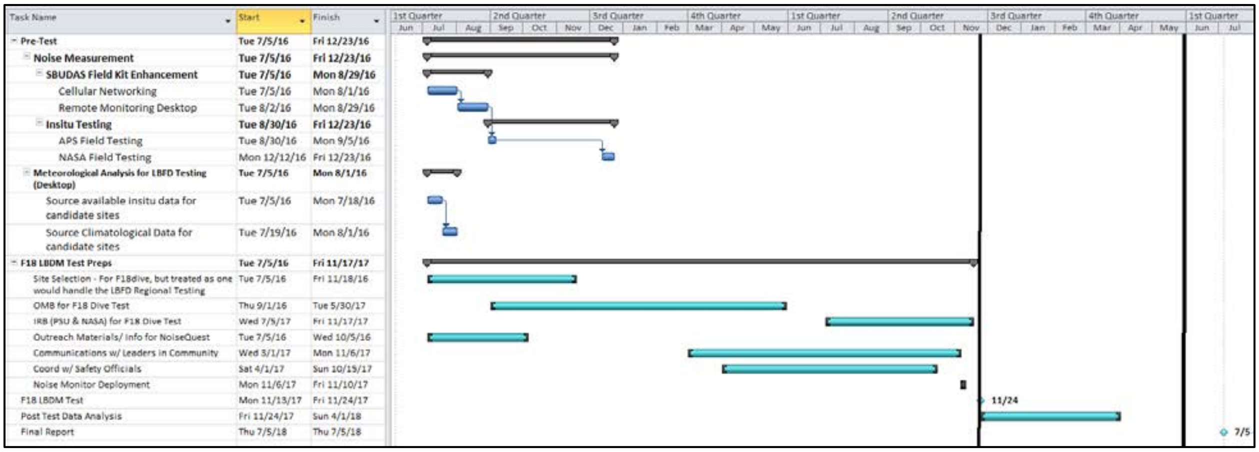


Figure 1-3 Risk identification, assessment, and prioritization process

1.4 Potential Mitigation Activities

One of the primary objectives for Phase 1 involved recommending key mitigation activities for high priority risks as identified in section 1.3. Risks involve activities related to the test participants and their responses (recruitment and acquisition of subjective data as well as social media response), the instrumentation to acquire data (noise and meteorological measurements and survey instruments) and the delivery of the noise dose (flight operations and environmental influences). These activities address hardware development, techniques for assessing an individual's location during the sonic boom exposure and conceptual test items such as effectiveness of site selection and community identification processes. Phase 2 risk mitigation activities, detailed later in Section 11, have been identified to culminate in an F-18 Low Boom Dive test in a non-acclimated community. Additional recommend activities beyond the originally proposed scope are identified in Section 12. A notional timeline for Phase 2 is included in Figure 1-4. While these activities will help address uncertainties and reduce risks for the future LBFD dose-response testing, the F18 Dive test does introduce a new risk: dive footprint and focus region placement. This will be different from the LBFD focus placement which is anticipated to have a greater separation from the community test region. Day of flight design of the F18 Dive Test and delivery of the desired amplitude low-boom signature to a community is heavily reliant on acquiring atmospheric upper-air data and prediction of the boom levels using PCBoom. While NASA pilots have delivered these with incredible degrees of success in the EAFB area, moving to another site with likely higher humidity and variable atmospheric parameters introduces a new risk which will need to be carefully assessed.



Task Name	Start	Finish
Pre-Test	**Tue 7/5/16**	**Fri 12/23/16**
Noise Measurement	**Tue 7/5/16**	**Fri 12/23/16**
SBUDAS Field Kit Enhancement	**Tue 7/5/16**	**Mon 8/29/16**
Cellular Networking	Tue 7/5/16	Mon 8/1/16
Remote Monitoring Desktop	Tue 8/2/16	Mon 8/29/16
Insitu Testing	**Tue 8/30/16**	**Fri 12/23/16**
APS Field Testing	Tue 8/30/16	Mon 9/5/16
NASA Field Testing	Mon 12/12/16	Fri 12/23/16
Meteorological Analysis for LBFD Testing (Desktop)	**Tue 7/5/16**	**Mon 8/1/16**
Source available insitu data for candidate sites	Tue 7/5/16	Mon 7/18/16
Source Climatological Data for candidate sites	Tue 7/19/16	Mon 8/1/16
F18 LBDM Test Preps	**Tue 7/5/16**	**Fri 11/17/17**
Site Selection - For F18dive, but treated as one would handle the LBFD Regional Testing	Tue 7/5/16	Fri 11/18/16
OMB for F18 Dive Test	Thu 9/1/16	Tue 5/30/17
IRB (PSU & NASA) for F18 Dive Test	Wed 7/5/17	Fri 11/17/17
Outreach Materials/ Info for NoiseQuest	Tue 7/5/16	Wed 10/5/16
Communications w/ Leaders in Community	Wed 3/1/17	Mon 11/6/17
Coord w/ Safety Officials	Sat 4/1/17	Sun 10/15/17
Noise Monitor Deployment	Mon 11/6/17	Fri 11/10/17
F18 LBDM Test	Mon 11/13/17	Fri 11/24/17
Post Test Data Analysis	Fri 11/24/17	Sun 4/1/18
Final Report	Thu 7/5/18	Thu 7/5/18

Figure 1-4 Preliminary Phase 2 Risk Reduction Activity Concept

1.5 LBFD Test Design and Approach Summary

This section includes a high-level outline for the LBFD Test Design, Risk identification and Mitigation Activities. Aspects of the design that could potentially be evaluated in F-18 low-boom dive field test to better identify and reduce the associated risks for future testing with the LBFD are detailed in Section 10.

Site Selection Approach (Section 2)

1. Select Climate Type: Hot/Humid, Hot/Dry, Marine, Cold/Very Cold, Mixed/Humid
2. Identify 6 geographically distinct regions around the country as the 6 test sites.
3. Identify Flight Support Infrastructure/Airport Selection
4. Identify flight path
5. Obtain Address Based Sampling (ABS based on U.S. postal service) for grids
6. Test Duration limited to < 1 month (consider seasonal/holiday influences)

Communications Strategies (Section 3)

Outreach Approach

1. Engaging the public through information and interactive learning experiences
2. Foster public understanding through education
3. Develop informational content designed to enhance knowledge, raise awareness
4. Identify research test based message content, determine potential information release options
5. A nationwide Supersonics Outreach plan is outside the scope of this effort

Consistent Approach Across sites

1. Form Outreach team with diverse agency membership
2. Require English speaking participants. (Our team is willing and able to accommodate multi-lingual survey for LBFD and Phase 2 testing if desired by NASA - requires scope and funding increment.)
3. Identify and work with leaders in local government, community organizations
4. Create content focus for individual communities

Community based Approach (To be finalized under Phase 2)

1. Subtle approach prior to conducting the field test
2. Media based approach after the field test
3. Develop an educational outreach plan to execute in multiple communities across each regional site
4. Develop informational content designed to enhance knowledge, raise awareness
5. Develop STEM materials available as downloadable on NQ for classroom use
6. Design and implement multi-method delivery approach

Communications Contingency Plans Leveraging ASCENT

1. Use social media monitoring tools to monitor posts in geographical area of test site
2. Monitor social media responses before, during and after the test
3. Use monitoring of social media as a soft sensor to alert us to extreme events
4. Monitor in areas with and without respondents under flight path
5. Identify and address any viral negative media with immediate press release

Communications Material

1. Content will be presented in a variety of formats in easy to read language
2. Written content would be associated with informative images
3. Content would be initially written using technical language to ensure accuracy, and then edited to simplify the reading level.
4. A reading level of 8th to 10th grade will be targeted to match the national reading level
5. Some content may not lend itself readily to a 10th grade reading level. Accuracy would be maintained, and the content would be simplified as much as possible.
6. Relevant video links would be identified to provide multi-media learning opportunities
7. Work with NASA sponsor to utilize NASA Outreach resources

Pre-test Community Engagement and Outreach

1. Assess local noise attitudes via social media monitoring. Is there already a noise issue?
2. Identify local options for News Media outlets: Printed, TV, Radio, Web-based, newsletters
3. Simulator Days: Use simulator to introduce/train a portion of the participants on low booms
4. Use Social media monitoring to observe community dynamics (leveraged through ASCENT as described in section 8.6))

Post-test Outreach Vision

1. Educate the public, present information with research based perspective
2. *Imagine* the future
3. *Inspire* future generations of students and travelers
4. *Share* advanced technology and underlying concepts
5. *Acknowledge* challenges
6. Multiple modes of presentation and interactions
7. STEM educational outreach options (Options finalized under Phase 2)

Subjective Assessment Approach: Implementation of Survey Instruments (4)

1. Baseline Survey Length up to 40 questions (12 pages)

2. Single Event web surveys
3. Daily Summary web surveys End of Day (EOD)[*]
4. IF night time flights are added, we can add an End of Night Survey.

Objective Assessment Approach: Field Instrumentation and Monitors (Section 6)
1. Optimize spatial arrangement of monitors within communities
2. Methodology for obtaining metrics at subject locations
3. Density of measurements
4. Uncertainty of Analytical (PCBoom) predictions in footprint zones
5. Utilize less expensive noise monitors to supplement the field kit monitor (affords increased density of noise monitors across area)
6. Documenting the full sonic boom exposure area
7. Atmospheric variability may warrant relocation or deployment of additional sensors
8. Assess impact of topography (geography and buildings)

Recruitment Approach (Section 7)
1. Implement Address Based Sample (ABS)
2. Target 6000 respondents in total across 6 geographically/climatically distinct regional test sites.
3. Target 1000 respondents per regional site
4. Pre-notification letter sent to 4000 addresses per test site. (Includes information on the project and directions for online contact survey. The project information will indicate this is a noise survey, but not yet detailed boom information. Specific language will be determined in Phase 2.)
5. Baseline survey Recruitment Mailing
6. Thanks for participation or Reminder Follow-Up Postcard (7 to 10 days later)
7. Final Recruitment Mailing (7 to 10 days later)
8. Interdependent Process

Subjective Data Analysis Approach (Sections 9.2 - 9.4)
1. Overall Design: Multiple communities
2. Six sites ~1000 participants per regional site, for ~6000 participants total
3. Noise dose includes off design operating conditions to provide a broader range of doses
4. Survey technology will identify respondent location at the time of the sonic boom
5. Participant’s work and home may be receive different sonic boom exposures
6. Between Participant Design: Affords comparison between participants for the same events
7. Between Community Design: Affords comparison across multiple communities

[*] Sleep disturbance is not included in the scope of this test plan and will require a separate substantial effort. Awakenings by participants who go to bed before the last flight or who might sleep during the days (i.e. night-shift workers) will not be included in this test plan. It is possible that working nights could be potential disqualification grounds during recruitment; however this has not yet been finalized. The design of the flight times (in progress) will also take this into consideration. For the LBFD test, there should be no sonic booms after 9 pm local time.

2. Region and Site Selection

One of the key elements of a future LBFD sonic boom dose-response test design is ensuring adequate representation of the US general population, which includes diversity in the site selection process. Region and site selection also encompass a variety of operational concerns – from ensuring a representative sample of climate zones (and hence building construction types) found across the United States, to identification of an airport or base with sufficient runway length and facilities to support NASA LBFD operations, to determining flight tracks which meet the performance limitations of the LBFD while placing focus and climb sonic booms appropriately, to the identification of communities with the desired variation in demographics and building types. Our test design utilizes a community recruitment approach, where people in a prominent community (home and work locations) are targeted for recruitment. This prominent community clustering facilitates the placement and maximizes the density of noise monitoring equipment in the vicinity of participants. This Section discusses our development of the selection process and presents six regional sites and two alternate sites for which detailed site exploration has been conducted (Figure 2-1). Additional details about the central United States site selection process may be found in Appendix E.

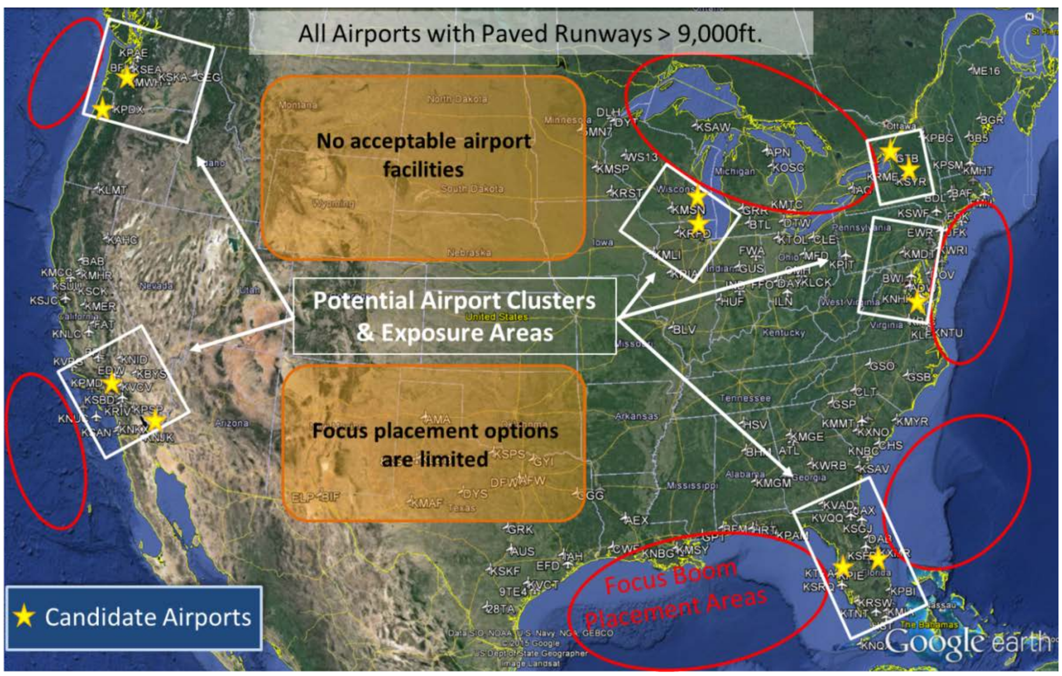


Figure 2-1 Potential Climates and Airports for Regional Bases of Operations

The process for selecting sites and communities is a hierarchical one (Figure 2-2) and starts with regional considerations then airport selection followed by area screening, preliminary flight track layout and finally identification of recruitment grid cells and community selection. This process will be explained in more detail in the following sections using the hot-humid region (central Florida) as an example. Data for the remaining five regional bases of operations are presented in Section 2.8.

Figure 2-2 Site Selection Hierarchy and Criteria

2.1 Regional Climate Considerations

In order to ensure the total participant population and geographic areas selected are representative of the entire United States, sites were initially chosen from one of five climate zones (Figure 2-3), as defined by Building America [Baechler *et al.,* 2013]. The climate zones are as follows; Cold, Marine, Hot-Humid, Mixed-Humid, and Hot-Dry. The Mixed-Dry and Very Cold climate zones were not used for site selection due to their relative small size and lack of large population areas. Two sites are under consideration from the Cold climate zone to account for its large geographical area and population relative to the other climate zones in the continental US. By selecting areas in each of these climate zones, we are able to represent a wide range of potential meteorological and atmospheric conditions, as well as community layouts and designs, building materials, and population densities.

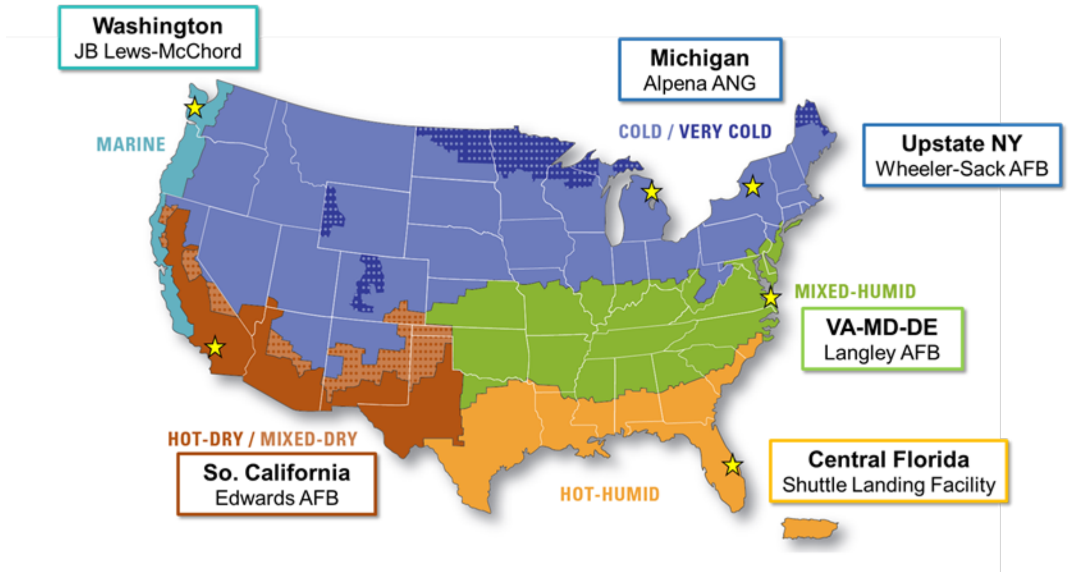


Figure 2-3 US Climate Zones and Preliminary LBFD Test Sites

2.2 Selection Process

Within the selected climate zone, a next-level search is conducted to determine viable airport facilities, or base of operations, with at least one runway with a length equal to or greater than 9,000 ft., as prescribed in the Statement of Work. Out of this new list of potential airports, those owned and/or operated by the United States government (Military or NASA) are given preference. If no such airports exist, airports with relatively empty surrounding airspace are considered higher priority. Continuing the process of adding more specific selection criteria, the resulting airport facilities are viewed on a map to determine their respective proximities to large bodies of water, or to areas with extremely low population density for the purpose of placing focus and climb signatures. Other considerations include the possibility of previously acclimated communities with regard to sonic booms, and also recent changes in commercial airport flight paths in and around the selected region (Metroplex Changes / FAA Airspace Redesign), which may have a negative or undesirable impact on community perception of sonic boom testing.

Once an appropriate airport site is found using the method described, a conceptual flight path must be created, illustrating the general direction of flight and location of turns if necessary. This is an inherently iterative process and during each design pass more details about the sites, geographic considerations and communities are uncovered and the selection adapted accordingly. By example, the Hot-Humid region was examined in more detail and is described in the next section, Section 2.3 Candidate Locations.

The general requirements for the flight path of the LBFD and the relative location of potential communities are outlined in the Statement of Work, and are as follows:

- At least 2 community exposures , 20+ minutes apart
- Closest community < 125 n.mi. from base of operations

- Exposure (boom carpet) approx. 50 n.mi. long by 35 n.mi. wide
- Supersonic range up to 350 n.mi
- Take-off and landing sites up to 500 n.mi apart

2.3 Candidate Locations

At present six candidate locations for future LBFD testing have been identified. They include two sites in the cold climate zone (NY and WI) and one each in Hot-Dry (CA), Hot-Humid (FL), Mixed-Humid (VA) and Marine (WA) as itemized in Table 2-1.

Table 2-1 Candidate Locations for LBFD Regional Testing

Climate Zone	Bose of Operations	Community Location(s)	Focus Placement Area	Notes
Hot-Humid	Shuttle Landing Facility	Central FL	Atlantic Ocean, Gulf of Mexico	Owned and operated by Space Florida as of June 22, 2015
Marine	Joint Base Lewis-McChord	WA State	Pacific Ocean	
Cold	Alpena County Regional Airport	MI, WI	Lake Michigan/Huron	Michigan Air National Guard Alpena Combat Readiness Training Center
	Wheeler-Sack AAF	Upstate NY	Sparsely populated area	
Mixed Humid	Langley AFB	VA, MD, DE	Atlantic Ocean	Co-located with NASA LaRC
Hot-Dry	Edwards AFB	Southern CA	Pacific Ocean	Co-located with NASA AFRC

For each candidate location in the various climate regions, population density is used to indicate the varying degree of "suburban/urban vs. rural" areas. Our plan is to recruit participants in both rural and suburban areas, under the flight path. The targeted number of recruits in the area is based on the census population data. We have adopted this approach so that our participants reflect the distribution of residents under the flight path. In combination, the six regional test sites and the targeted communities within each site, represent a range of population densities as reflected in the site selection dashboards (Figure 2-9). Potential operational sites were identified which meet the runway, airspace and operational requirements for the LBFD. Using the Hot-Humid site as example, Figure 2-4 illustrates possible facilities and runways (yellow stars) and possible focus and carpet boom areas (carpet – red box, focus – curved red area). Corresponding graphics for the other climate zones may be found in Sections 2.8.1 to 2.8.5. Identification of the flight tracks to achieve the desired sonic boom coverage is an iterative process, strongly driven by the selection of prominent communities to be exposed to the sonic boom stimuli. This is discussed in more detail in Section 2.6.1.

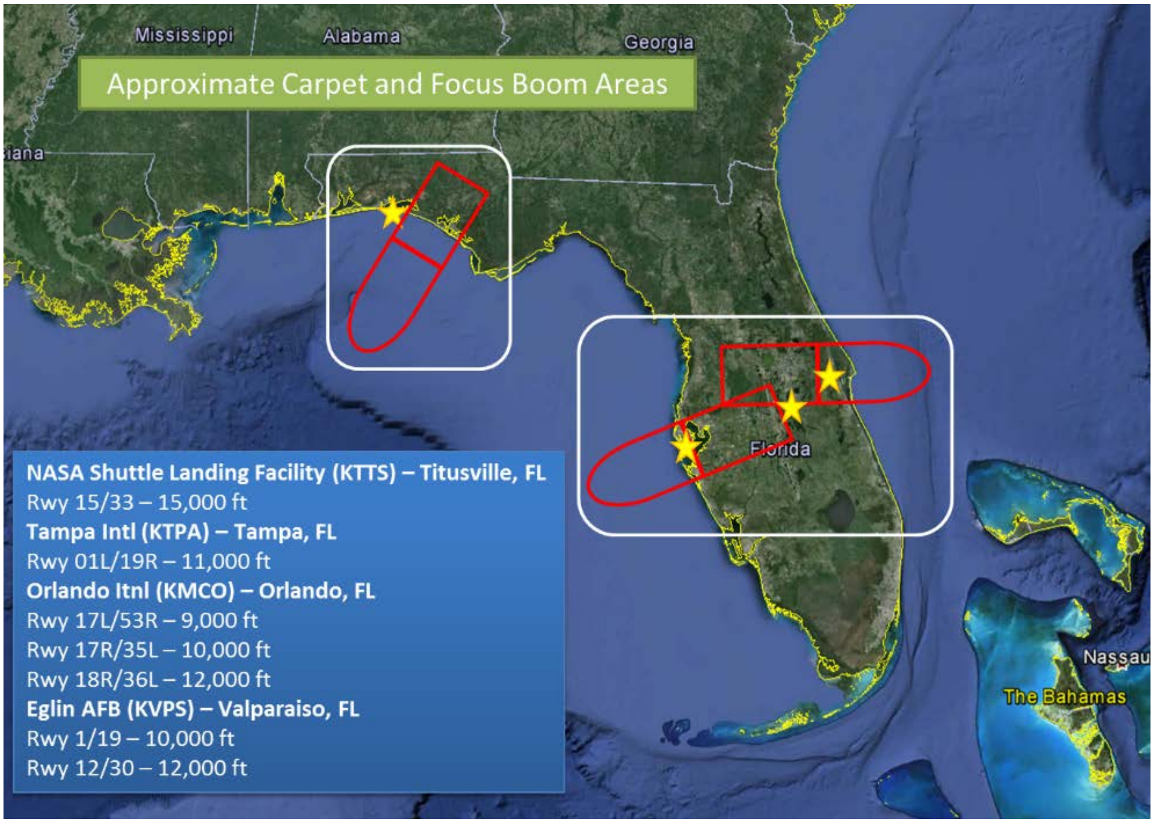


Figure 2-4 Potential Operational Sites, Hot-Humid Region

2.4 Supplemental Locations

Potential Operational Sites have been identified for each of the climate zones. Additional airport facilities are selected within each climate zone to ensure that there are viable secondary options if the primary selections are not available. One of the major benefits of choosing government controlled facilities is their relative flexibility of operations compared to commercial facilities. However, it is still necessary to plan for unexpected scheduling conflicts at all regional sites. In addition, the site selection process should consider FAA Metroplex changes around selected sites to reinforce that field test participants are responding to the low boom noise, and not to recent changes in commercial aircraft overflight noise, in order to ensure the integrity of the survey response data. The FAA Metroplex effort is realigning flight paths to maximize airspace efficiency, optimize on time arrivals and minimize fuel consumption. The associated noise impacts are sometimes also being relocated, to areas that previously weren't under a flight path. As such, some community members have recently been exposed to an increase in the aviation noise environment. We are conducting a pyscho-social listening task, in which we are asking respondents to evaluate an impulsive low boom noise that is a new aviation noise source in the local noise environment. The respondents may still be adjusting to the new noise source due to changes in overflight noise. The ratings for low boom may be influenced by attitudes that are a result of the overflight noise, not the low boom noise. Our findings would be more definitive in an area with residents that did not just experience recent changes in aviation noise background. An additional recommendation was to avoid areas with pending noise related litigation, in deference to all parties, including community members, local groups or government entities, airports or FAA, and to ensure our field test remain neutrals with respect to ongoing considerations of noise impact in that area. If residents are engaged in, or exposed to a polarized debate on aviation noise, their responses may reflect attitudes towards that debate, and not to the low boom noise. We need to control for as many variables as possible while we conduct this field based test of noise perception.

2.5 Selection of Communities Process (Hot-Humid Region)

After selecting an appropriate base of operations and creating a conceptual flight path, an approximate exposure area is overlaid on to a map of population density [U.S. Census Bureau, 2010]. Communities in the exposure (boom carpet) area are selected through the use of geographic "grid cells", that divide the exposure area (50 n.mi. by 35 n.mi.) into twelve separate cells (Figure 2-5). There are three rows of cells across the carpet: center line, azimuths approximately -15^{o} to +15^{o}; sideline, azimuths 15^{o} to cutoff. Within each grid cell, a community is chosen based on its relative prominence compared to the other communities in the same cell (Figure 2-6). Usually (but not always), the largest community in each cell is chosen to represent that grid cell for participant recruitment. "Prominent" communities may be found by using an interactive 2010 U.S. Census map of designated "census places", which gives a general sense of where populations are located and how large the absolute populations are. Care is given to select a balanced azimuthal distribution of communities across the flight track for the on-design LBFD flight condition as specified by NASA (Mach=1.6 Alt=50kFt). The three rows of grid cells represent different lateral azimuth ranges – Centerline grid cells are approximately -15° to +15°, Lateral grid cells are approximately right and left: 15° to 50°. Additional details about the lateral sonic boom distribution may be found in Section 5.2.

The identified prominent communities are then researched in more detail to identify potential noise issues which suggest possible bias. As needed the interactive census geographic data is revisited to select more communities. A list of screening items is contained in Table 2-2.

When a prominent community (and alternates) are selected, the geographic boundaries are obtained. This information will then be shared with the team members responsible for recruitment, where the selected areas are screened for the availability and quality of Address Based Sampling (ABS) data. Those not meeting minimum ABS requirements will be dropped and replaced with alternate prominent communities. During the selection process the prominent community characteristics are notated. A list of the community characteristics is provided in Table 2-3. Characteristics refers to differences among community members because of their ethnic backgrounds, language, or customs. Immigrants may choose to live in communities that are concentrated enclaves of individuals speaking a similar language and engaging in community dynamics supported by their culture. We need to be aware of groups of individuals that may not be English speaking, but are under the low-boom carpet. The ultimate prominent communities selected will include a wide range of characteristics so as to be representative of the whole United States while facilitating testing various other aspects of the test plan – such as government communication, community outreach. We will strive to obtain a sufficient number of communities to support the statistical analysis and will not attempt to target any singular distribution found at the national level. We are seeking to recruit sufficient participants to have valid data analysis.

As such, we are using addressed based sampling and accepting those who volunteer to participate. We are not targeting the national distribution of demographic characteristics, as we acknowledge that the national demographic distribution comes from combining distinct communities across the country, and individual communities will not likely reflect that same distribution.

Table 2-2 Community Screening Items – Disqualification criteria

Item	Description
1	Active FAA Metroplex or Local Airport Flight Track Redesign / Airport Expansion Activity
2	Activist communities w/ anti-Government tendencies (identified via Social Media, Bloggers, Online websites etc…)
3	Community with active lawsuits or pending litigation against Airport or Aviation Operations
4	Close proximity to Military base with significant flight operations (Fixed or Rotary Wing)

Table 2-3 Prominent Community Characteristics

Population Density
Building Construction Type
Demographics
Division / Location of School Districts (outreach)
Science centers / museums (outreach)
Government Structure
Background noise
Cellular Network Coverage
Prevalence and proximity to urban work centers
Cultural
Azimuthal Position across carpet
Geographic / terrain features

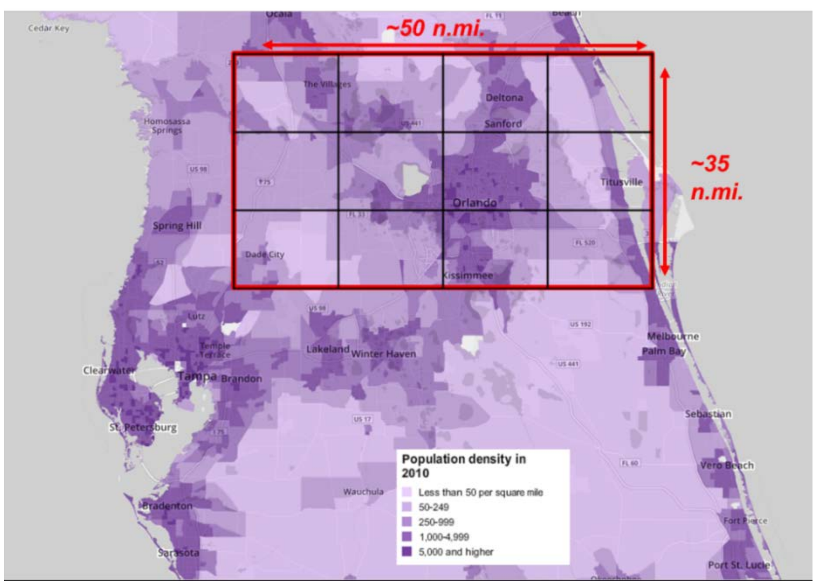


Figure 2-5 Community Population Density Grid, Hot-Humid Region

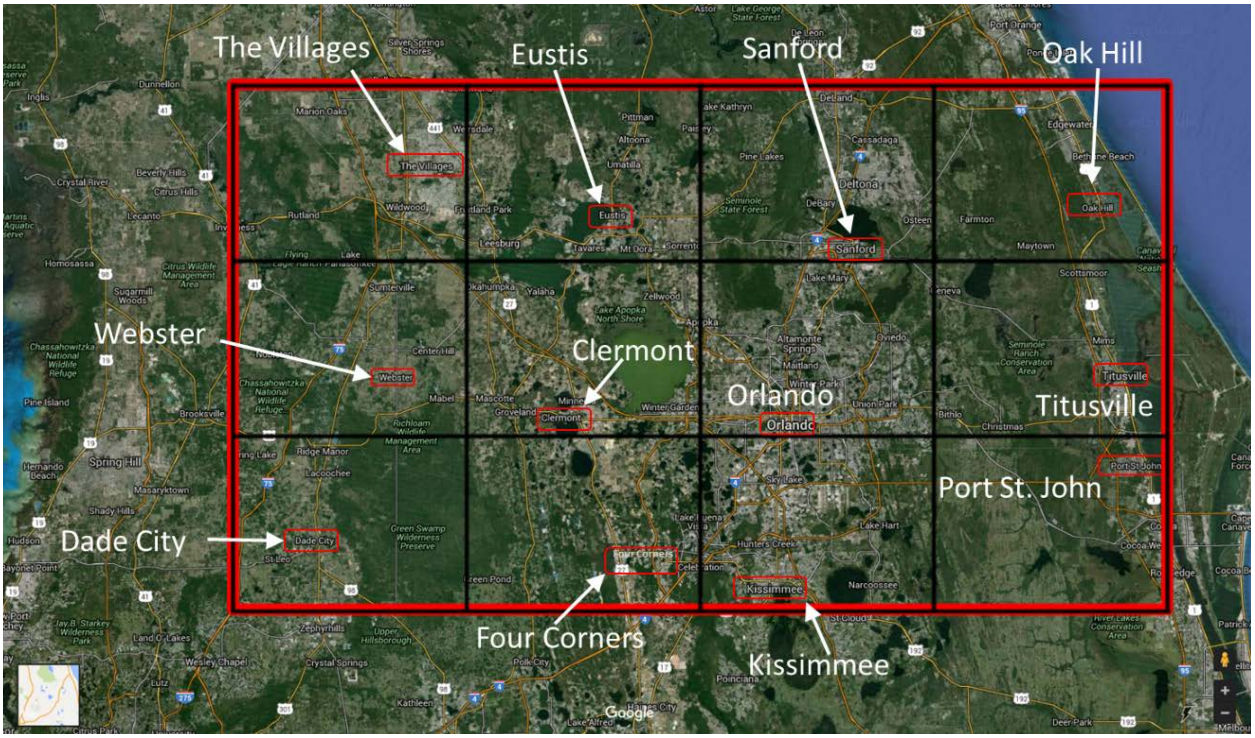


Figure 2-6 Identified Prominent Communities in Grid Cells, Hot-Humid Region

Recruitment target numbers are calculated by distributing the desired number of participants proportionally by population across the twelve selected communities. The participant numbers for each community were then multiplied by a factor that adjusts for response rate (approx. 25% positive response), resulting in a total number of "targeted recruits" that would be necessary to attain the desired number of participants (Figure 2-7). A composite dashboard of the demographics for these prominent communities are provided in Figure 2-9. The prominent community demographics and standard deviation distribution data is based on State Demographic data [U.S. Census Bureau, 2000; U.S. Census Bureau, 2009] with the exception of the US Hispanic/Latino and Non-Hispanic Latino data which was derived from Ennis *et all.* [2011]. The Community population demographics graphics are based on digital data [U.S. Census Bureau, 2010]. Further information about the demographics in each prominent community may be found in Appendix A. Additional community information, such as school districts needed for community outreach (Section 3.1) may be found in Figure 2-8.

Population

The Villages 51,000	Eustis 19,000	Sanford 54,000	Oak Hill 1,800
Webster 1,000	Clermont 29,000	Orlando 240,000	Titusville 45,000
Dade City 6,500	Four Corners 26,000	Kissimmee 60,000	Port St. John 12,300

% of Recruitment Area Population

The Villages 9.35	Eustis 3.48	Sanford 9.90	Oak Hill 0.33
Webster 0.18	Clermont 5.32	Orlando 43.99	Titusville 8.25
Dade City 1.19	Four Corners 4.77	Kissimmee 11.00	Port St. John 2.25

Recruits (1000 Total)

The Villages 94	Eustis 35	Sanford 99	Oak Hill 4
Webster 2	Clermont 53	Orlando 440	Titusville 83
Dade City 12	Four Corners 48	Kissimmee 110	Port St. John 23

ABS Targets Required (assuming 25% response)

The Villages 376	Eustis 140	Sanford 396	Oak Hill 16
Webster 8	Clermont 212	Orlando 1760	Titusville 332
Dade City 48	Four Corners 192	Kissimmee 440	Port St. John 92

Figure 2-7 Proportional Recruitment Targets by Cell, Hot-Humid Region

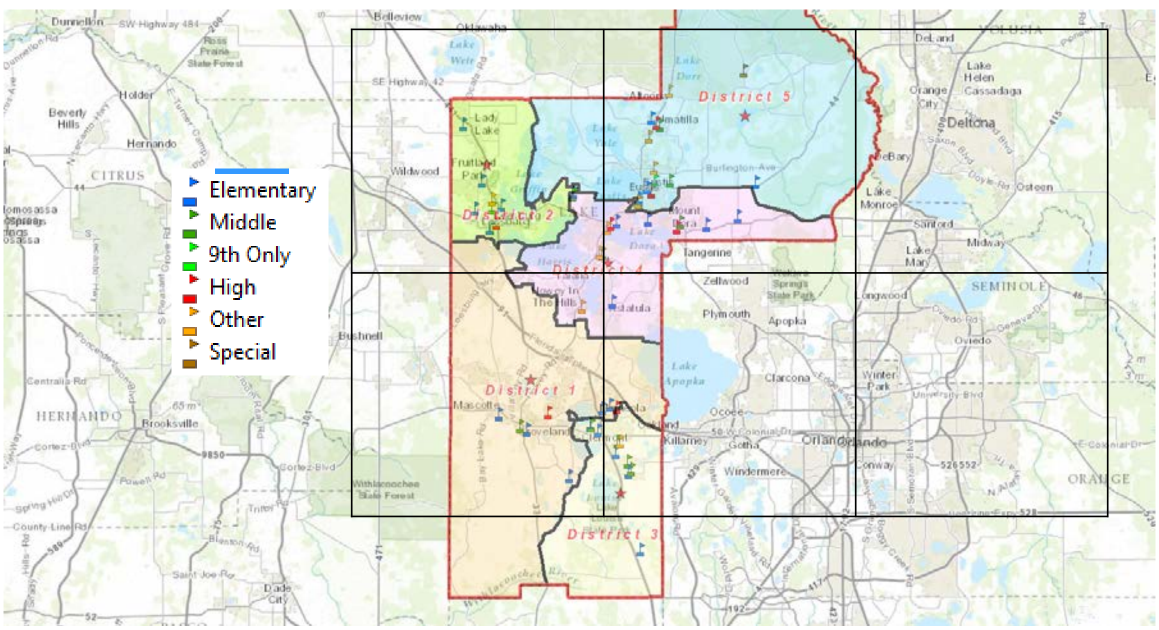


Figure 2-8 Lake County School Districts, Central FL

Figure 2-9 Prominent Community Demographics Dashboard, Hot-Humid Region

2.6 Flight Operations

2.6.1 Flight Path Design

As stated in Section 2.2, after an appropriate base of operations has been determined for a specific climate zone, a conceptual flight path is created over the surrounding area so that the estimated exposure (boom carpet) area includes large population centers. The layout of flight trajectories occurs in conjunction with the desired community exposure cells and is an iterative process. Once the exposure area is set, the flight path is extended to show the path from the airport runway to the start of the on-design sonic boom carpet portions of the community noise exposure, including any turns that may be necessary to achieve the correct headings. The initial climb and acceleration to the cruise Mach will likely result in a focused sonic boom, though concurrent analysis by aircraft manufacturers suggests the focal zone could potentially be minimized with a suitable climb schedule.

A flight track has been laid out that will provide two community passes for each flight operation with the vehicle decelerating to subsonic speeds in between flight passes (Figure 2-10). Additional guidance and data from NASA (flight performance and engine characteristics) will be needed to further refine these flight operation designs in the future to ensure they properly represent the anticipated performance of the future LBFD test aircraft. Also additional analysis using historical meteorological data should be conducted when selecting to identify a possible range of supersonic flight tracks to deliver the desired sonic boom on the communities when accounting for the propagation effects of seasonal wind and temperature profiles on the ground booms.

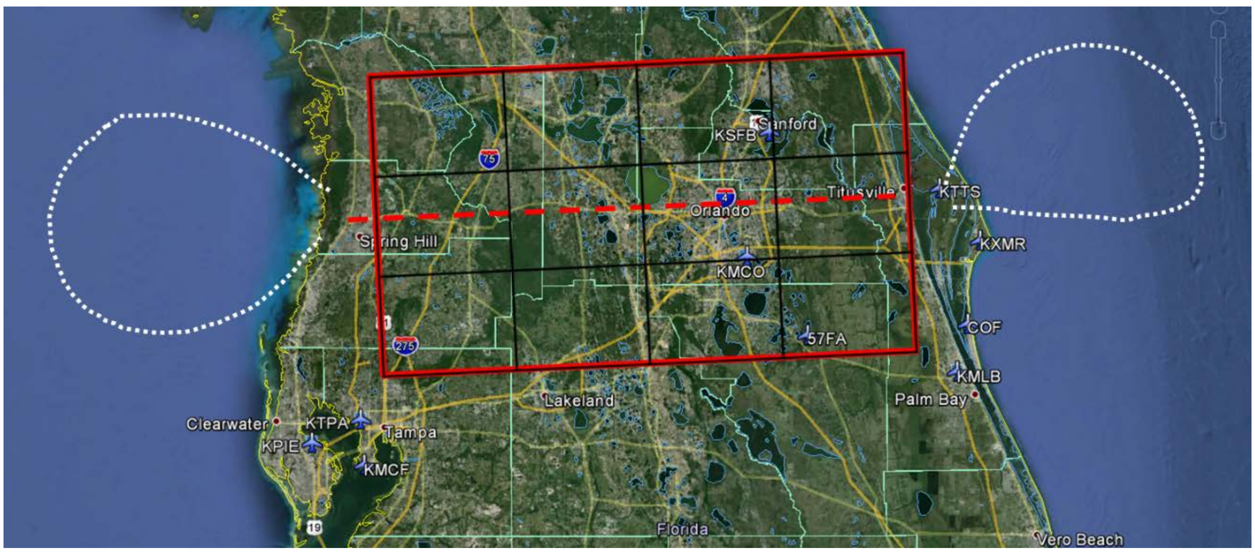


Figure 2-10 Proposed Flight Track from Selected Base of Operations, Hot-Humid Region

These turns could potentially result in focus booms if the aircraft is travelling at supersonic speed, so it is necessary to design the total flight path such that focus booms are mitigated or placed over areas with very little or no population. The results presented in this section rely on several approximations – all of which will need to be revisited as the LBFD design is refined and built. These approximations include:

- Vehicle cruise source characteristics are based on the NASA LBFD Design [Ordaz et al., 2015]
- Climb profile is based on nominal aerodynamic characteristics developed by Gulfstream
- Off-design source characteristics were not utilized in the analysis presented here. In the future

off-design characteristics can be modeled in PCBoom[†] via CFD analysis and cylinder inputs based on climb profile Mach and C_L requirements.

2.6.2 Focus Boom Placement

The placement of potential focus booms is a major component of the site selection and flight operation procedure. Turn focus may be avoided by reducing to subsonic speeds following a sonic boom community pass and exposure while positioning the aircraft for any subsequent flight passes. Using aircraft performance information and the PCBoom software suite, approximate pressure contours have been modeled and plotted under the proposed flight paths to determine if and where focus booms might exist. One of the important criteria in site selection is proximity to large bodies of water and/or sparsely populated areas, precisely for the purpose of placing focus booms away from large communities.

Focus booms may or may not occur due to turns depending on the parameters of each maneuver, which can be modeled in PCBoom to determine if a focus exists. If the flight path requires turn over a populated community, the aircraft must be decelerated below supersonic to avoid any boom altogether. This will necessitate another acceleration from subsonic to supersonic speed with its unavoidable transition focus boom region followed by the climb to cruise condition. Figure 2-11 illustrates to scale a climb transition focus to climb to cruise sonic boom footprint and overpressure levels for the Hot-Humid Region for a westbound flight. The subsonic to supersonic transition focus is the higher amplitude (psf) contours on the eastern portion of the footprint. And nominal cruise conditions are achieved at the eastern seaboard. During detailed operational design once the LBFD has been designed, this analysis will need to be revisited using the LBFD aircraft flight performance capabilities.

[†] PCBoom V6 can model varying source characteristics during climb boom based only on changes in Mach number. For examination in the future of optimized climb profiles this capability will need to be expanded to include additional parameters.

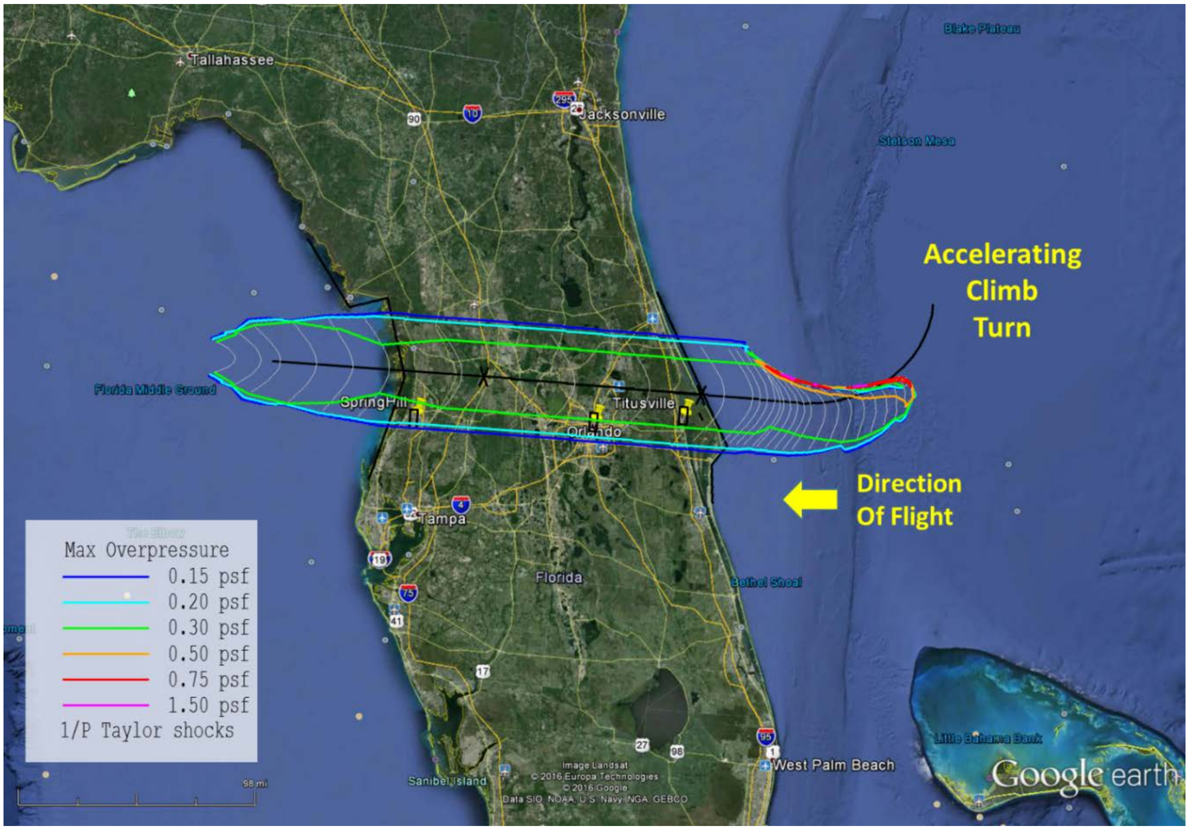


Figure 2-11 Climb Acceleration Flight track, Focus & Carpet Sonic Boom Footprint, Hot-Humid Region

2.7 Logistics

The logistics for the defined LBFD test design will be described in this section and includes a nominal timeline for execution of the test plan. The roles and responsibilities of WSPRRR team members are described and where identified explicitly, the roles and responsibilities of NASA are itemized. In addition to the high-level planning schedule, identification of supporting tasks are outlined including the following:

- Prominent Community Selection Finalization
- Interaction with local, state and federal government representatives
- Development of OMB and IRB packages
- Accommodations for LBFD basing and operations and supporting flight test requirements
- Recruitment
- Field communications protocols
- Instrumentation site selection, acquisition and installation
- Data gathering tasks (subjective, objective, meteorological, social monitoring)
- Post test data archiving, analysis and reporting

LBFD Logistics Timeline - *Repeated for each Regional Test (with calendar overlap)*								
	Quarter							
	1	2	3	4	1	2	3	4
Prominent Community Selection Finalization								
Detailed Exploration	Δ-----	----------Δ						
Selection of Prominent Communities			Δ---Δ				Δ	
Work Centers	Δ-----	----------Δ						
Interaction with local, state and federal government representatives								
Identification of Representatives					Δ----Δ			
Government Contact (State and Community)							Δ	
Outreach (Identification & Execution)			Δ----Δ					Δ---Δ
FAA Contact (Preliminary, Final Notification & Coordination)				Δ		Δ		
Development of OMB and IRB Packages								
Package Preparation & Submission				Δ-----	-----------	----------Δ		
Coordination with NASA IRB					Δ---------Δ			
Acommodations for LBFD Flight Support								
Candidate Airfield Identification		Δ---------Δ						
NASA Coordination re: Aircraft Flight Ops Support			Δ--------	-----------	-----Δ			
Recruitment								
Region ABS recruitment in Prominent Communities							Δ------Δ	Δ
Incentive Disbursement								Δ
Field Communication Protocols								
Protocol Development		Δ----Δ						
Master Cellular list distribution							Δ	
Instrumentation Site Selection, Acquisition, Installation								
Specific Instrumentation Sites Scoped / Visited / Selected				Δ-----	-----------	----------Δ		
Installation of Instrumentation							Δ----Δ	
Data Gathering								
Social Media Monitoring							Δ-----	
Flight Test Data								
Post test data archiving, analysis and reporting								
Data Archive								Δ
Analysis								Δ------Δ
Reporting								Δ

Prominent Communities Finalized

Regional Flight Test Execution

Figure 2-12 Logistics Timeline

2.7.1 Prominent Community Selection Finalization

During the detailed test design process (at least one year prior to each Regional Flight Test Execution), for each Climate Region the features of each of the prominent communities will be revisited to ensure that they still meet the selection criteria (Section 2.5) and provide, in combination, a good overall representation of the United States. Alternate prominent communities will be identified. The final Prominent Community Selection recommendations will be reviewed by NASA at least one year prior to each Regional Flight Test Execution.

Work centers, indicated by clusters of businesses, "downtown" area or regions with office parks or high-rise office space, shopping malls and the like, will be identified within the on-design carpet area for each regional site. Points of contact for these work centers (as appropriate) will be identified in the event supplemental recruitment is needed at work centers. This information will also be leveraged during the recruitment process and will be potentially utilized for placement of additional monitoring equipment.

2.7.2 Interaction with local, state and federal government representatives

As part of the Prominent Community Selection Finalization process, the local and state government organizations and points of contacts for various representatives (Table 2-4) will be identified. Their organizational structure and authoritative relationships will be determined via indirect means.‡

Table 2-4 State, Prominent Community and Local Organization Points of Contact to be identified

State Representatives	Prominent Community Representatives	Others Possible Outreach
State Governor – Executive Branch	Community elected or appointed leader for Local Government (Commissioner, County, City)	Colleges and Universities including community colleges,
State Department of the Environment (or equivalent) with environmental protection oversight	Health Department Representative	Local Media outlets including News Stations, Radio, State, Regional and town newspapers and online publications
State Department of Education overseeing public schools.	First Responders / Safety Headquarters Community Liaison	School system board of education public liaison and Science Department Chair
State Department of Health (or equivalent) overseeing and regulating health-related issues	Police Headquarters/ Commissioner Community Liaison or Public Safety Officer for relevant Bureaus	Local Museums or Science Centers Outreach / Education Office or Department
State Legislative Branch – Senators and Delegates for the Prominent Communities		Airports, Heliports and Hobbyist Flight fields (radio controlled aircraft)
		Libraries and Community Centers and Meeting Locations

In order to facilitate identification of suitable locations for noise monitoring and meteorological instrumentation, potential government buildings (with alternatives) will be identified in each prominent community along with their points of contact. This task will be closely coordinated with the detailed design of the instrumentation layout. During the identification process no information regarding the LBFD testing intentions will be disclosed.

Local Media outlets including News Stations, Radio, State, Regional and town newspapers and online publications will be identified by the WSPRRR team in advance of the Flight Test. During the last quarter before the flight test the NASA public affairs office will verify that communication lines are open with these organizations to ensure they can be readily accessed in the event immediate press releases need to be made during the test execution.

Potential partners for outreach and points of contact will be identified. These might include colleges and universities in the region as well as libraries, schools, museums, science centers (Table 2-4). As described in the Community Engagement and Outreach Section (Section 3) outreach will only begin after

‡ Direct contact will not be made with individuals until such a time as 1) NASA has made a final decision on the detailed LBFD test plan and given the go-ahead and 2) IRB and OMB approvals have been obtained.

the flight testing has been concluded.

Coordination with the FAA will be the responsibility of NASA. This coordination will include obtaining necessary airspace supersonic flight authority and other airspace logistics regarding flight operations. Preliminary discussions with the FAA will be approximately 1 year in advance of each Regional Flight Test. Final airspace requirements will be identified by NASA based on the flight operations portion of the test plan for each region. These will be determined jointly by NASA and the WSPRRR team at least 6 months prior to test execution. It is likely that the LBFD manufacturer is also involved in the operational flight design.

2.7.3 Development of OMB and IRB packages

The preparation of OMB and IRB applications shall be the responsibility of the WSPRRR team as described in Section 4.6. NASA has indicated that they will take the lead on submission to the OMB. Coordination between the PSU and NASA IRBs will be as dictated by NASA. OMB and IRB approvals shall be obtained prior to any recruitment or discussions with points of contact at regional sites or prominent communities. It is anticipated that approvals will be needed at least 3 months prior to test execution.

2.7.4 Accommodations for LBFD basing and operations and supporting flight test requirements

The WSPRRR team will identify, in conjunction with NASA, suitable bases of operations for each regional test. It will be the responsibility of NASA to coordinate with these airfields regarding accommodations for the LBFD and flight operations support associated with the operation of the aircraft.

2.7.5 Recruitment

Section 7 describes our tiered recruitment process, starting with identification of households using ABS sampling. Recruitment can commence after all IRB and OMB approvals have been obtained and after the final prominent communities have been selected and approved by NASA. It is anticipated that recruitment will take 6-8 weeks to conduct for each regional test. Recruitment will be the responsibility of the WSPRRR team.

2.7.6 Field communications protocols

Communication protocols will be developed by the WSPRRR team during the detailed flight test design at least one year prior to each regional test. This will include identification of regional cellular carriers and coverage extent / strength. This information will facilitate selection of prominent communities and determination of the detailed instrumentation layout and site selection. Any communication frequency approvals required shall be obtained by NASA. The primary communication mechanism is expected to be smart phone / cellular / email for which explicit permissions are not required, but to which all personnel are expected to have access. One month prior to each regional flight test a master cellular communications list will be developed and distributed to the team. A mechanism for updates will also be established. The following positions have been identified:

NASA Flight Test Director – Responsible for overall test execution and safety, including flight operations, daily Go/No-go decision, calculation of flight operation way-points and for coordination with the Test Directors.

Dose-Response Test Director – Contractor responsible for overseeing overall execution of the flight test plan, including both subjective and objective data gathering.

Subjective Data Director – Responsible for overseeing daily subjective data gathering, interactions with test participants, coordination with community leaders and outreach efforts.

Objective Data Director – Responsible for overseeing daily objective data gathering, ensuring acoustic and meteorological instrumentation is functional, calibrated and operational; identification of cellular network status, providing timely meteorological data to the NASA Flight Test Director.

Acoustic Lead – Responsible for acoustic instrumentation including network, daily calibration, testing and identifying operational status to the Objective Data Director, data gathering/ back-up / archival / daily reporting to the test directors.

Survey Lead – Responsible for ensuring survey instrumentation is operational, coordination with participants as needed, data gathering / back-up / archival / daily reporting to the test directors.

Field Crew – This comprises everyone involved in the data gathering whether they are on-location at the regional test site or involved remotely with data gathering (i.e. survey research center personnel tasked with oversight of incoming data, remote acoustic system monitoring personnel)

Protocols for in-field communications will include the following communication paths (arrows indicate directions of communications):

- NASA Flight Test Director → Data Directors / Leads / Field Crew (Go/No-Go, test specific daily info etc.) NASA shall determine the most appropriate method – email, web, dedicated flight-status phone line (recording), etc.
- NASA Flight Test Director ←→ Aircraft Pilot / Flight Operations – as determined by NASA
- NASA Flight Test Director ←→ Objective & Subjective Data Directors & Leads
- Objective Data Field Crew ←→ Objective Data Field Crew (Cellular, email, text messaging)
- Social Media Monitoring Crew ←→ Subjective Data Director
- Flight Operations → Subjective & Objective Data Field Crew (up to the minute information on aircraft operations, airborne, on-condition calls, return-to-base)

2.7.7 Instrumentation site selection, acquisition and installation

Detailed site selection is considered during the Prominent Community Selection process, however the exact locations (homes, buildings or other sites) will not be fully identified until recruitment has been initialized. Attempts will be made to identify the majority of locations based on population density and the recruitment ABS sampling random selection. (This can be done prior to mailing the first batch of recruitment postcards). Government buildings and other sites will be identified one quarter after the prominent communities have been finalized. Alternate sites will also be identified. Installation will be conducted so that all sites are operational one week prior to flight testing. This will permit assessment of background levels, adjustments as needed to site locations and system calibration.

2.7.8 Data gathering tasks (subjective, objective, meteorological, social monitoring)

Prior to the flight test, social media monitoring will be conducted as described in Section 8.6. The timing of this will be as recommended by the ASCENT program researchers, however it is expected there will be two periods of monitoring – one period at least 2 quarters prior to the flight test and a second period within the quarter immediately preceding the test. This will allow for the establishment of baseline levels prior to the LBFD test and permit researchers to identify subtle regional characteristics related to this subject area.

Subjective and Objective data gathering will be conducted in accordance with the designs as described in Sections 4 and 5, respectively.

Meteorological data will be gathered as described in Section 6.2 to a) assess the upper air conditions and facilitate a Go/No-Go decision as warranted b) determine the flight way-points for test execution and c) permit post-test analysis.

2.7.9 Post test data archiving, analysis and reporting

All data will be downloaded from their respective instrumentation / data systems and backed-up on at least two supplemental locations on a daily basis. Prior to shipping any equipment following the test, data will be separated and sent back via separate means (i.e. in personal luggage on a car/plane or via FedEx or via digital upload to a server). Posttest analysis will be initiated immediately following the test execution. Data reporting shall include the suggested analyses and graphics as identified in Section 9 and reported to NASA in both verbal and written formats.

2.8 Summary Regional Site Aggregate Data

Section 2.5 explained the community selection process in detail. The same process was followed for the other five regional testing locations. The key information for the Marine Region, Cold Region 1 and 2, Mixed-Humid Region and Hot-Dry Region may be found in Sections 2.8.1 to 2.8.5 respectively. For each climate region the following information is presented:

- Potential sites for flight operations
- Community population density grid
- Identified prominent communities in grid cells
- Proportional recruitment targets
- Prominent community demographics dashboard
- Potential flight track from selected base of operations

2.8.1 Marine Region - Olympia, WA – Joint Base Lewis-McChord

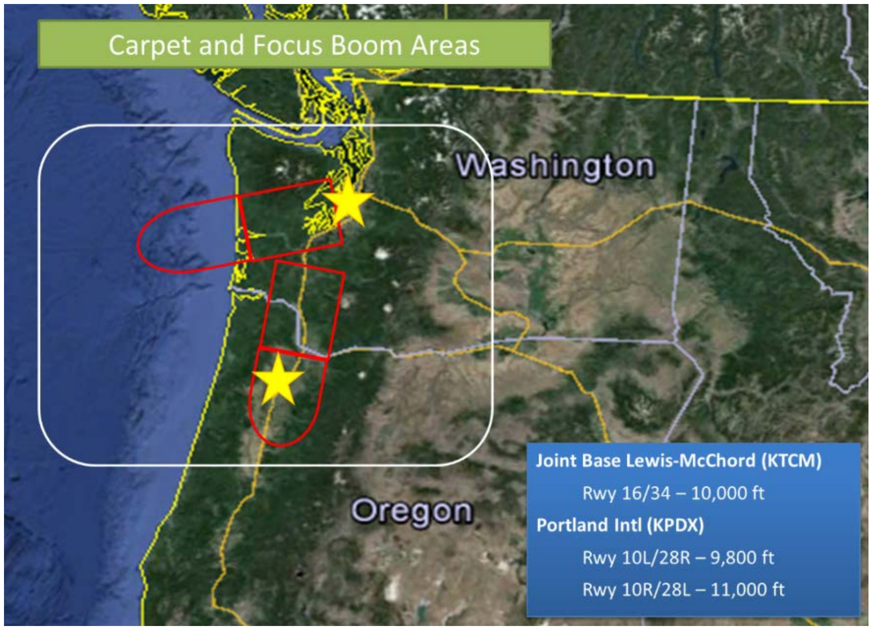


Figure 2-13 Potential Operational Sites – Marine Region

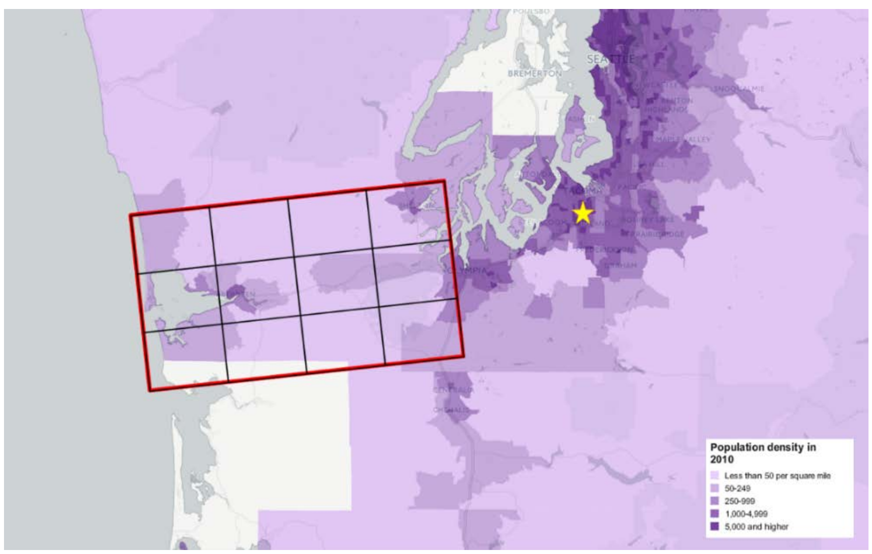


Figure 2-14 Community Selection / Population Density Grid, Marine Region

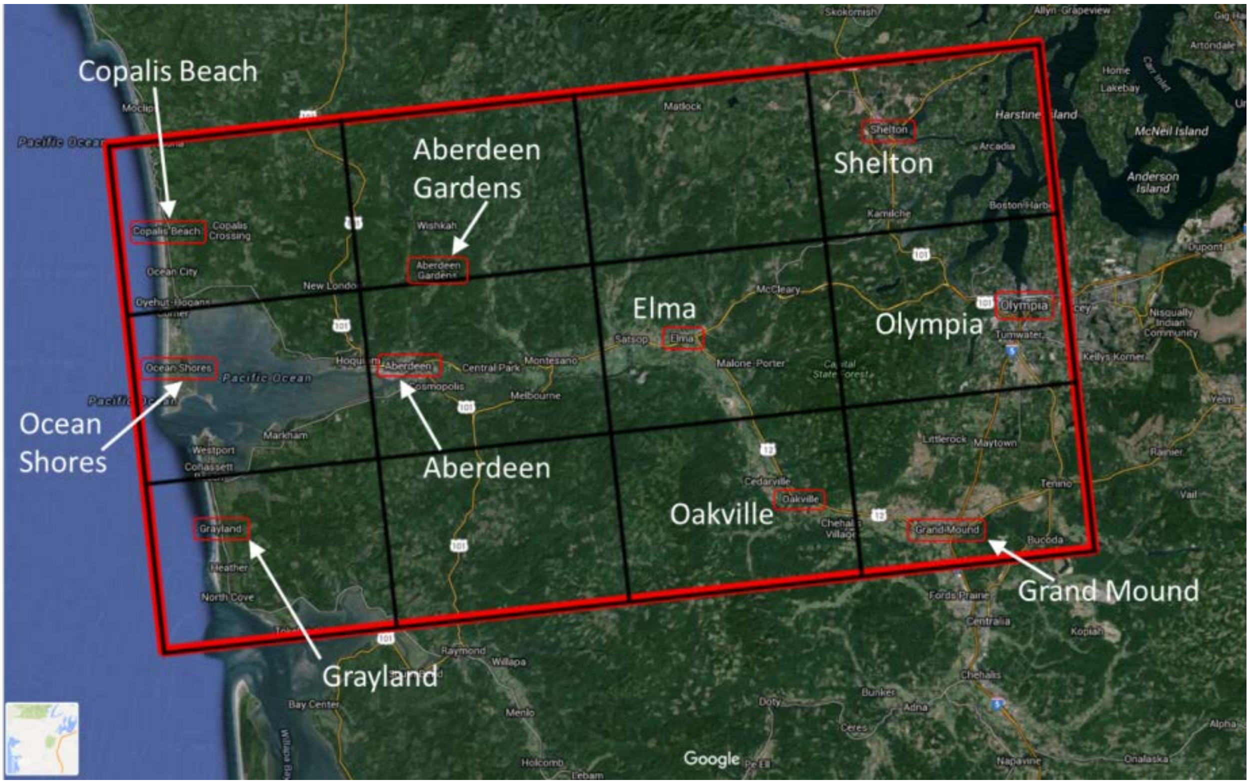


Figure 2-15 Identified Prominent Communities in Grid Cells, Marine Region

Population

Copalis Beach 415	Aberdeen Gardens 279	n/a	Shelton 9,834
Ocean Shores 5,569	Aberdeen 46,896	Elma 3,107	Olympia 46,478
Grayland 953	n/a	Oakville 684	Grand Mound 2,981

% of Recruitment Area Population

Copalis Beach 0.35	Aberdeen Gardens 0.23	n/a	Shelton 8.19
Ocean Shores 4.63	Aberdeen 41.51	Elma 2.58	Olympia 38.67
Grayland 0.79	n/a	Oakville 0.57	Grand Mound 2.48

Recruits (600 Total)

Copalis Beach 3	Aberdeen Gardens 2	n/a	Shelton 82
Ocean Shores 46	Aberdeen 415	Elma 26	Olympia 387
Grayland 8	n/a	Oakville 6	Grand Mound 25

Targets Required (assuming 22% response)

Copalis Beach 14	Aberdeen Gardens 9	n/a	Shelton 328
Ocean Shores 185	Aberdeen 1,660	Elma 103	Olympia 1,547
Grayland 32	n/a	Oakville 23	Grand Mound 99

Figure 2-16 Proportional Recruitment Targets, Marine Region

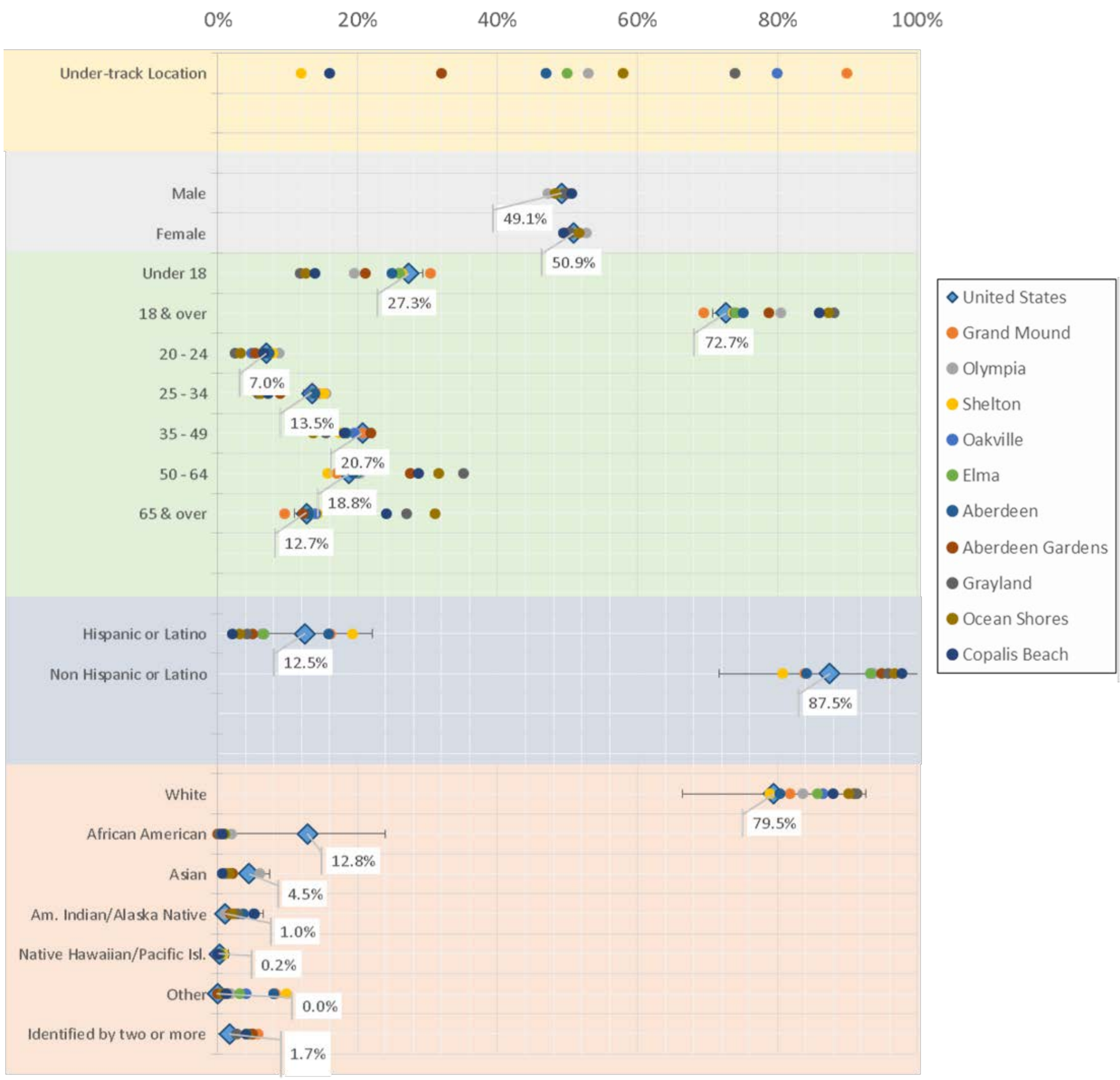


Figure 2-17 Prominent Community Demographics Dashboard, Marine Region

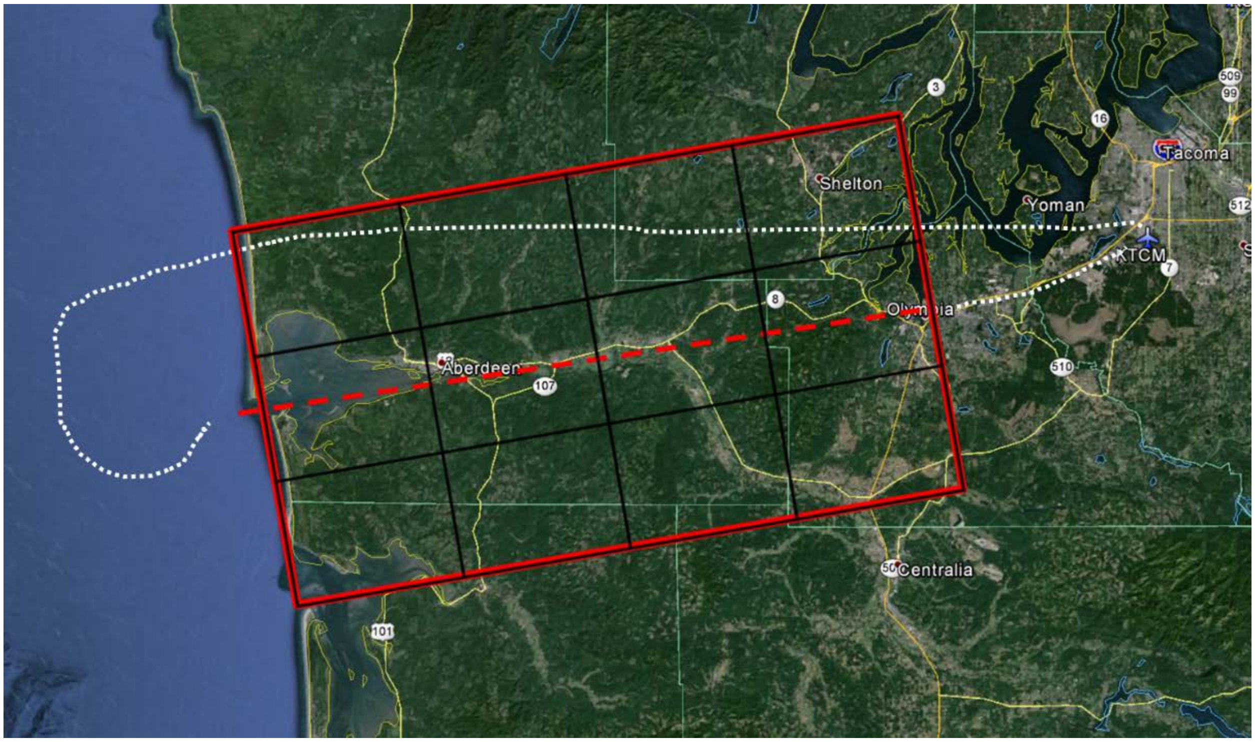


Figure 2-18 Potential Flight Track from Selected Base of Operations, Marine Region

2.8.2 Cold Region 1 – Saginaw, MI – General Mitchell International Airport

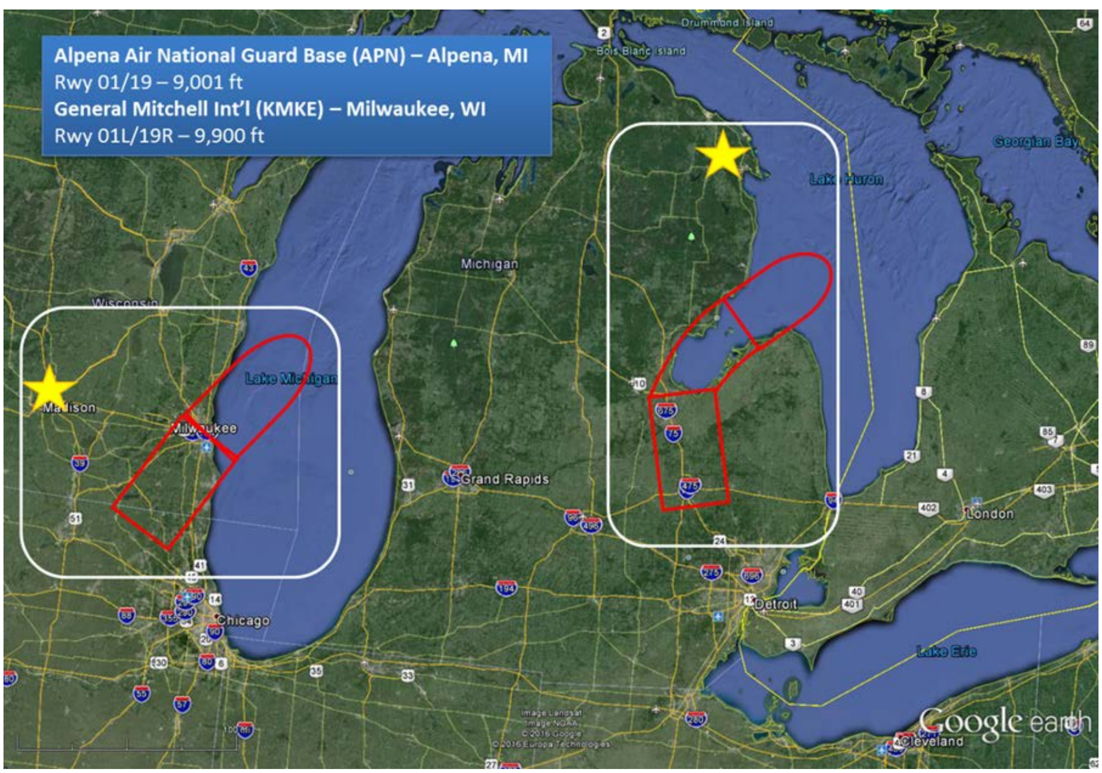


Figure 2-19 Potential Operational Sites – Cold Region 1

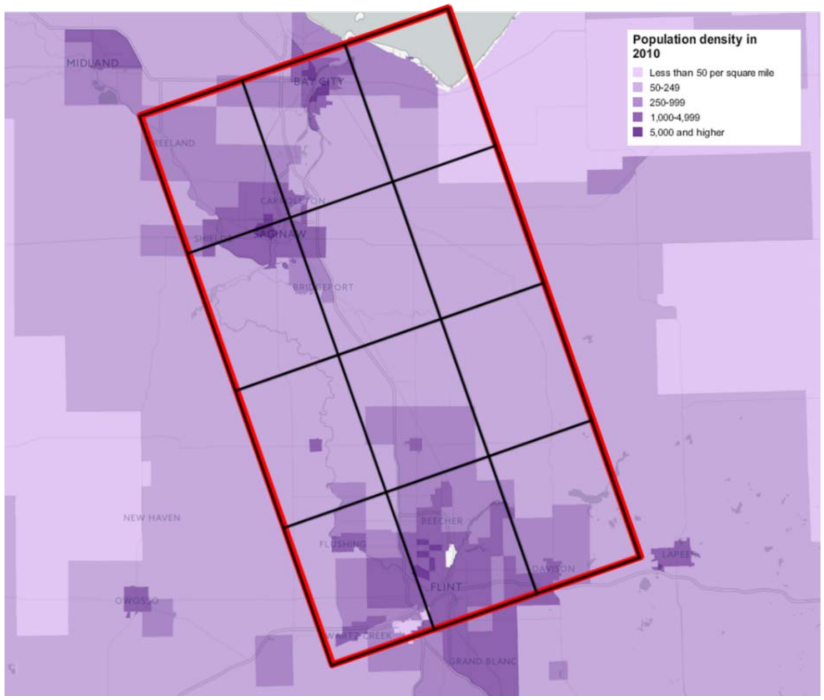


Figure 2-20 Community Selection / Population Density Grid, Cold Region 1

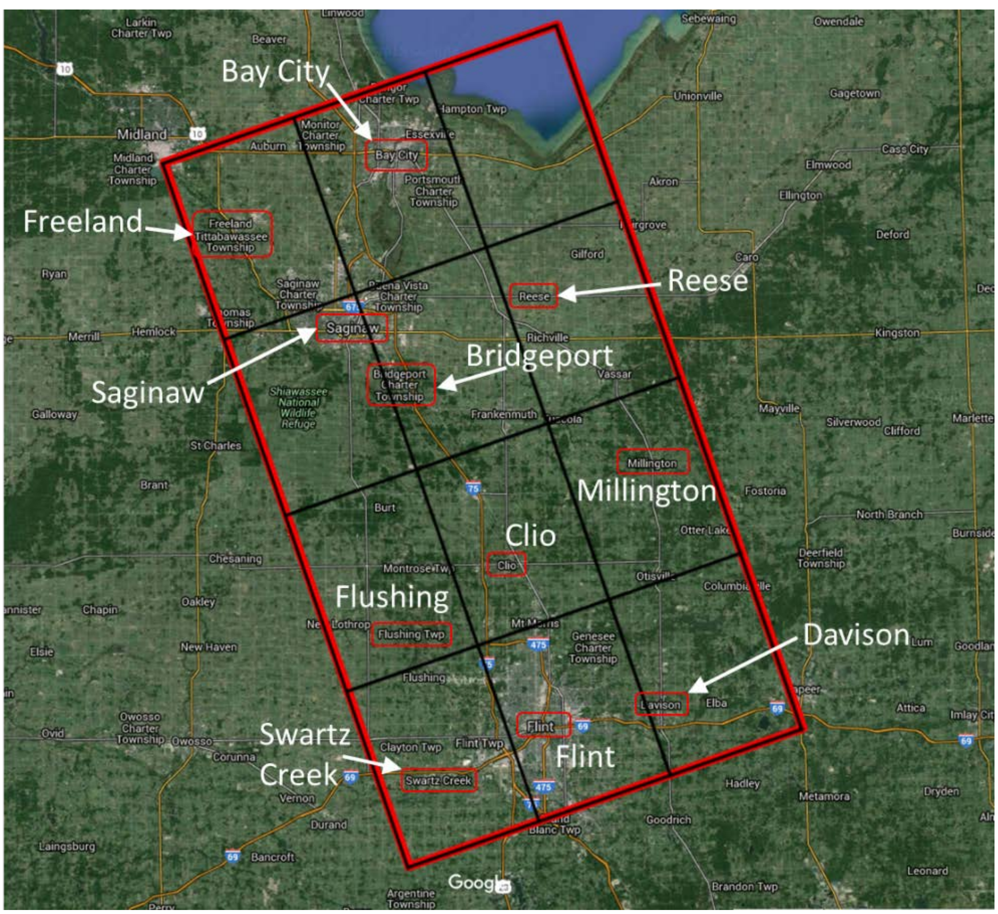


Figure 2-21 Identified Prominent Communities in Grid Cells, Cold Region 1

Population

n/a	Reese 1,454	Millington 1,072	Davison 5,173
Bay City 34,932	Bridgeport Twp 6,950	Clio 2,646	Flint 102,434
Freeland Twp 6,969	Saginaw 51,508	Flushing 8,389	Swartz Creek 5,758

% of Recruitment Area Population

n/a	Reese 0.64	Millington 0.47	Davison 2.28
Bay City 15.37	Bridgeport Twp 3.06	Clio 1.16	Flint 45.07
Freeland Twp 3.07	Saginaw 22.66	Flushing 3.69	Swartz Creek 2.53

Recruits (600 Total)

n/a	Reese 6	Millington 5	Davison 23
Bay City 154	Bridgeport Twp 31	Clio 12	Flint 451
Freeland Twp 31	Saginaw 227	Flushing 37	Swartz Creek 25

Targets Required (assuming 22% response)

n/a	Reese 26	Millington 19	Davison 91
Bay City 615	Bridgeport Twp 122	Clio 47	Flint 1803
Freeland Twp 123	Saginaw 906	Flushing 148	Swartz Creek 101

Figure 2-22 Proportional Recruitment Targets, Cold Region 1

Figure 2-23 Prominent Community Demographics, Cold Region 1

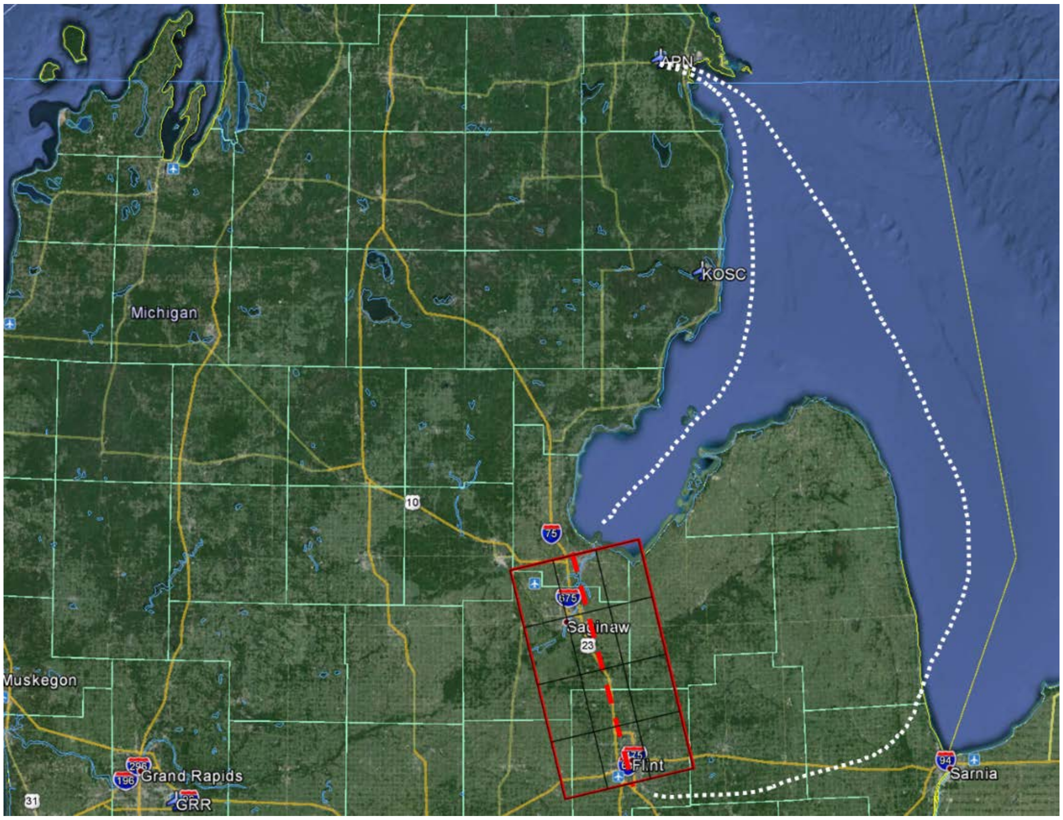


Figure 2-24 Potential Flight Track from Selected Base of Operations, Cold Region 1

2.8.3 Cold Region 2 – Upstate NY – Wheeler-Sack AAF

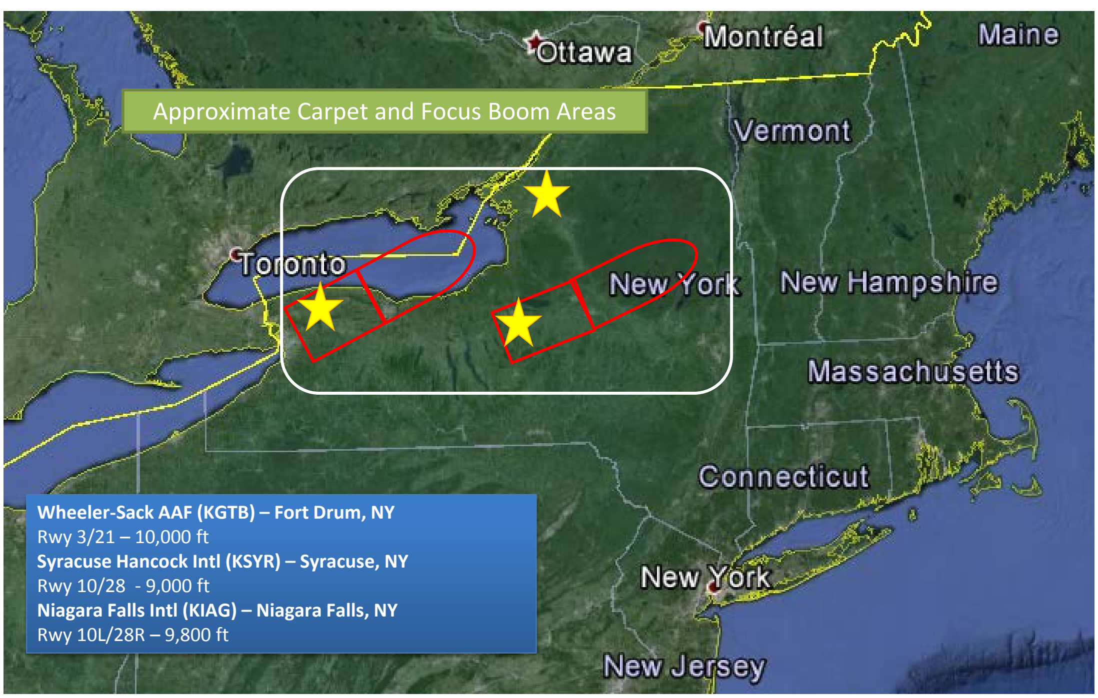


Figure 2-25 Potential Operational Sites – Cold Region 2

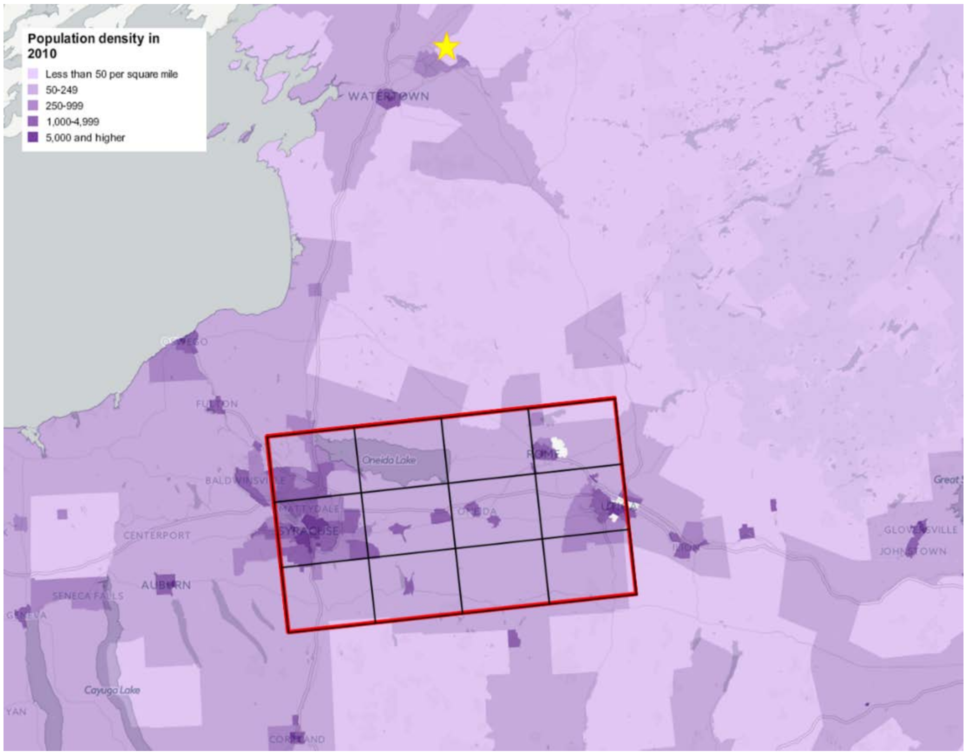


Figure 2-26 Community Selection / Population Density Grid, Cold Region 2

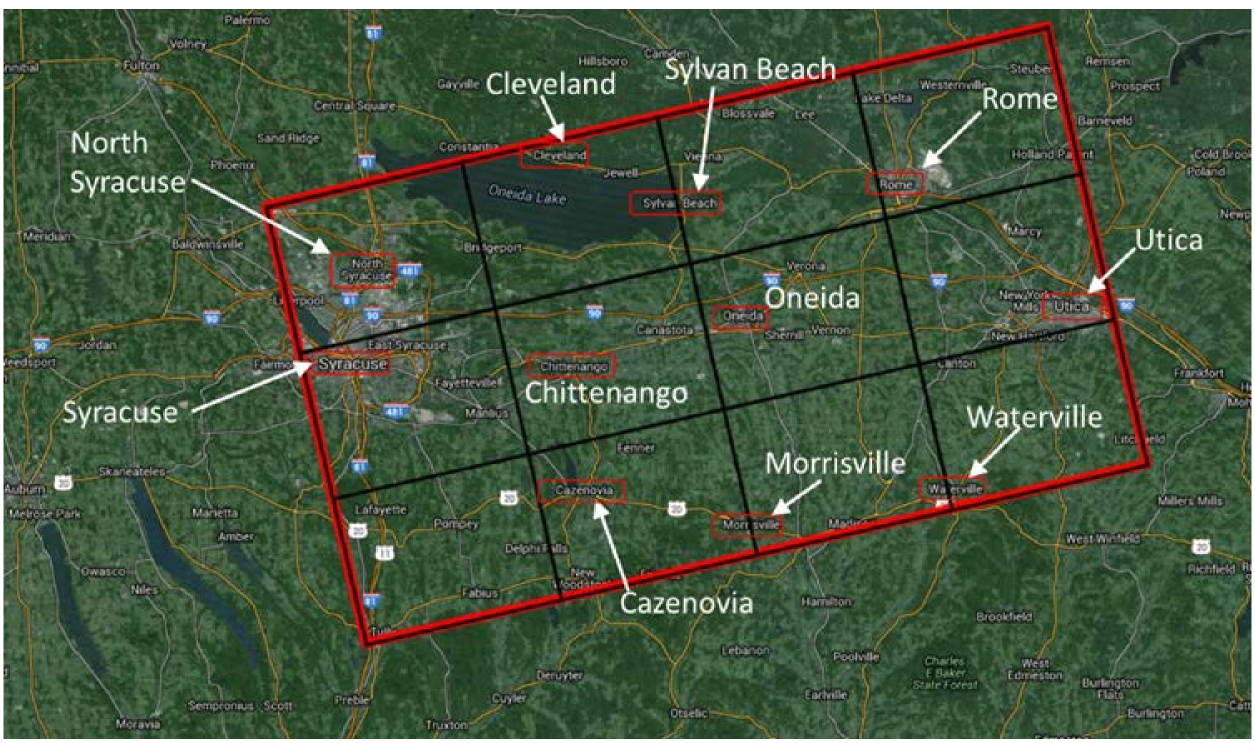


Figure 2-27 Identified Prominent Communities in Grid Cells, Cold Region 2

Population

N. Syracuse 6,800	Cleveland 750	Sylvan Beach 897	Rome 33,725
Syracuse 145,170	Chittenango 5,081	Oneida 11,393	Utica 62,235
n/a	Cazenovia 2,835	Morrisville 2,199	Waterville 1,583

% of Recruitment Area Population

N. Syracuse 2.49	Cleveland 0.28	Sylvan Beach 0.33	Rome 12.37
Syracuse 53.24	Chittenango 1.86	Oneida 4.18	Utica 22.82
n/a	Cazenovia 1.04	Morrisville 0.81	Waterville 0.58

Recruits (1000 Total)

N. Syracuse 25	Cleveland 3	Sylvan Beach 3	Rome 124
Syracuse 532	Chittenango 19	Oneida 42	Utica 228
n/a	Cazenovia 10	Morrisville 8	Waterville 6

Targets Required (assuming 22% response)

N. Syracuse 100	Cleveland 11	Sylvan Beach 13	Rome 495
Syracuse 2130	Chittenango 75	Oneida 167	Utica 913
n/a	Cazenovia 42	Morrisville 32	Waterville 23

Figure 2-28 Proportional Recruiting Targets, Cold Region 2

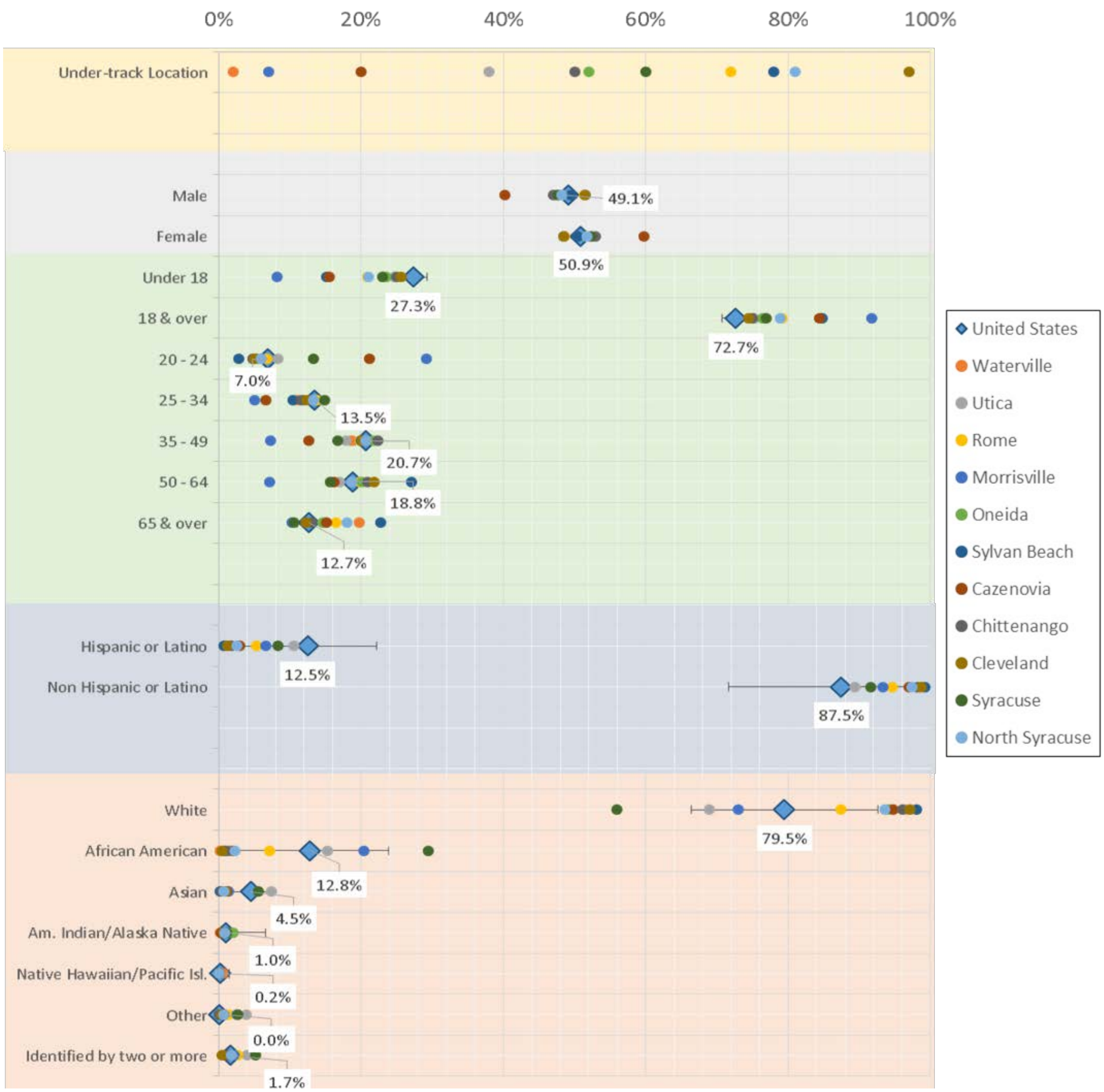


Figure 2-29 Prominent Community Demographics, Cold Region 2

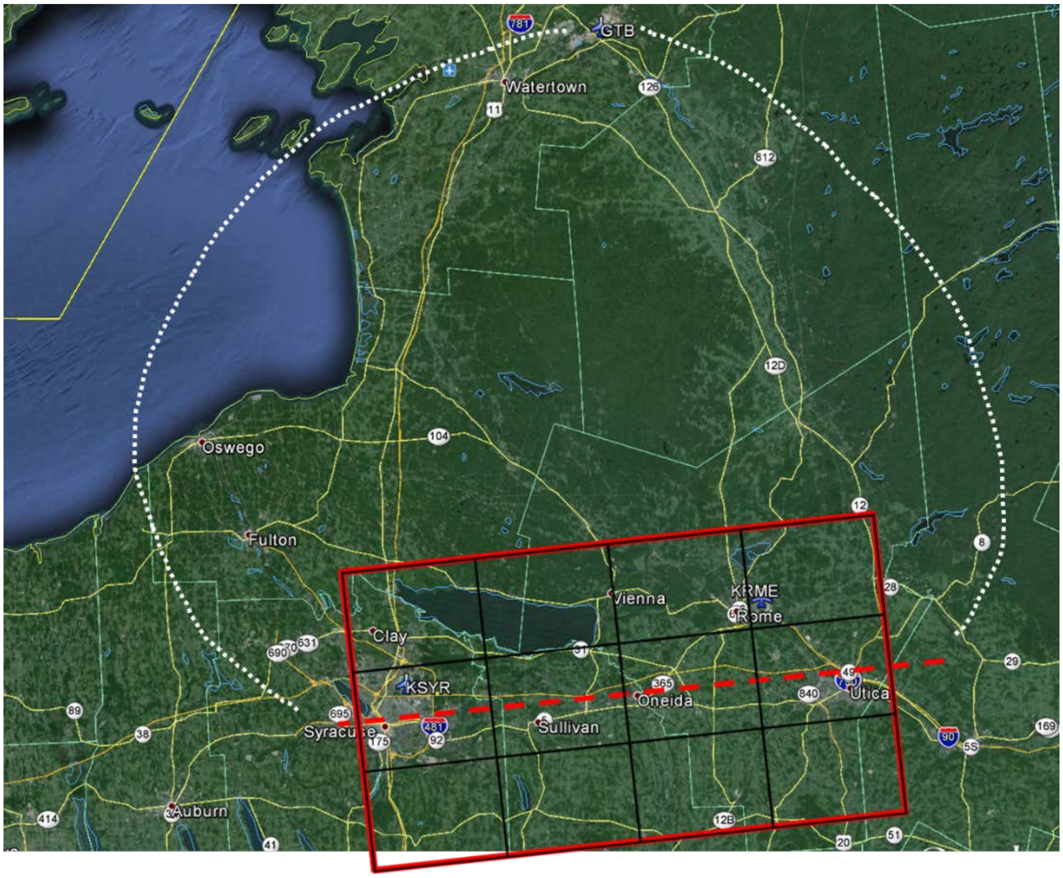


Figure 2-30 Potential Flight Track from Selected Base of Operations, Cold Region 2

2.8.4 Mixed-Humid Region –VA, MD, DE Area – Langley Air Force Base

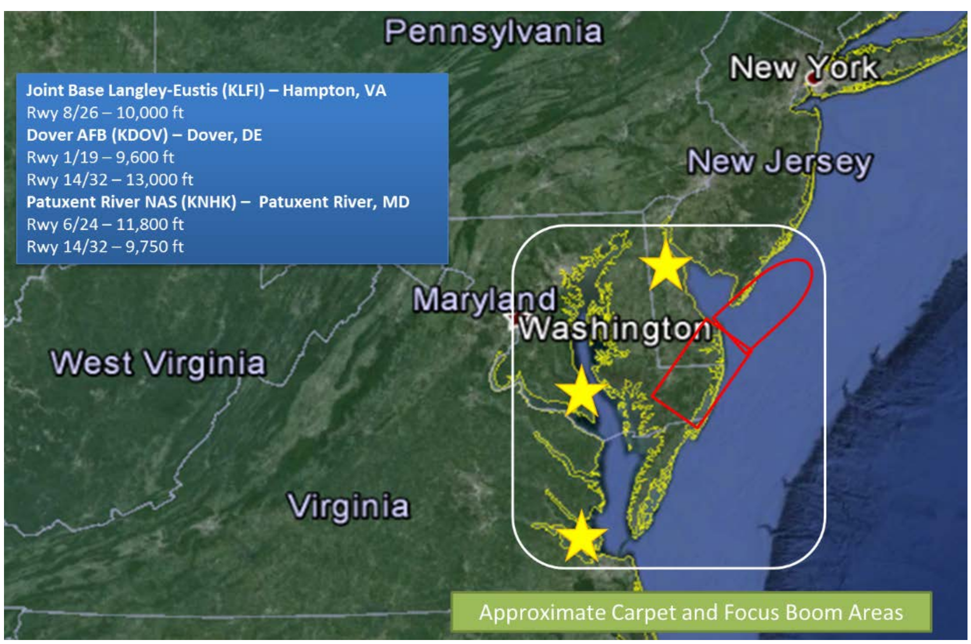


Figure 2-31 Potential Operational Sites – Mixed-Humid-Region

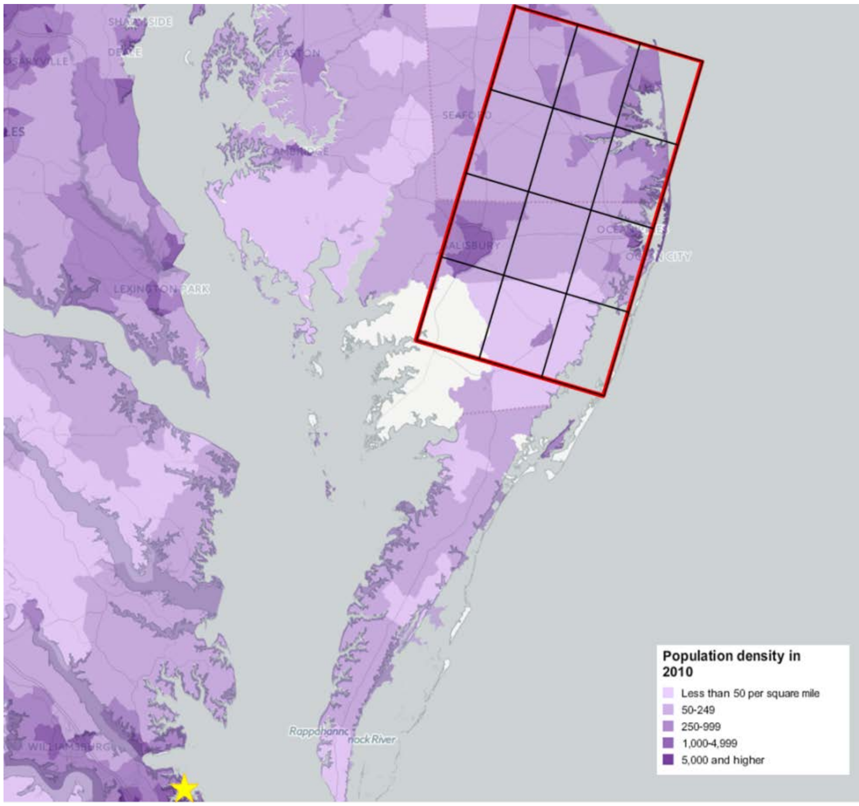


Figure 2-32 Community Selection / Population Density Grid, Mixed-Humid Region

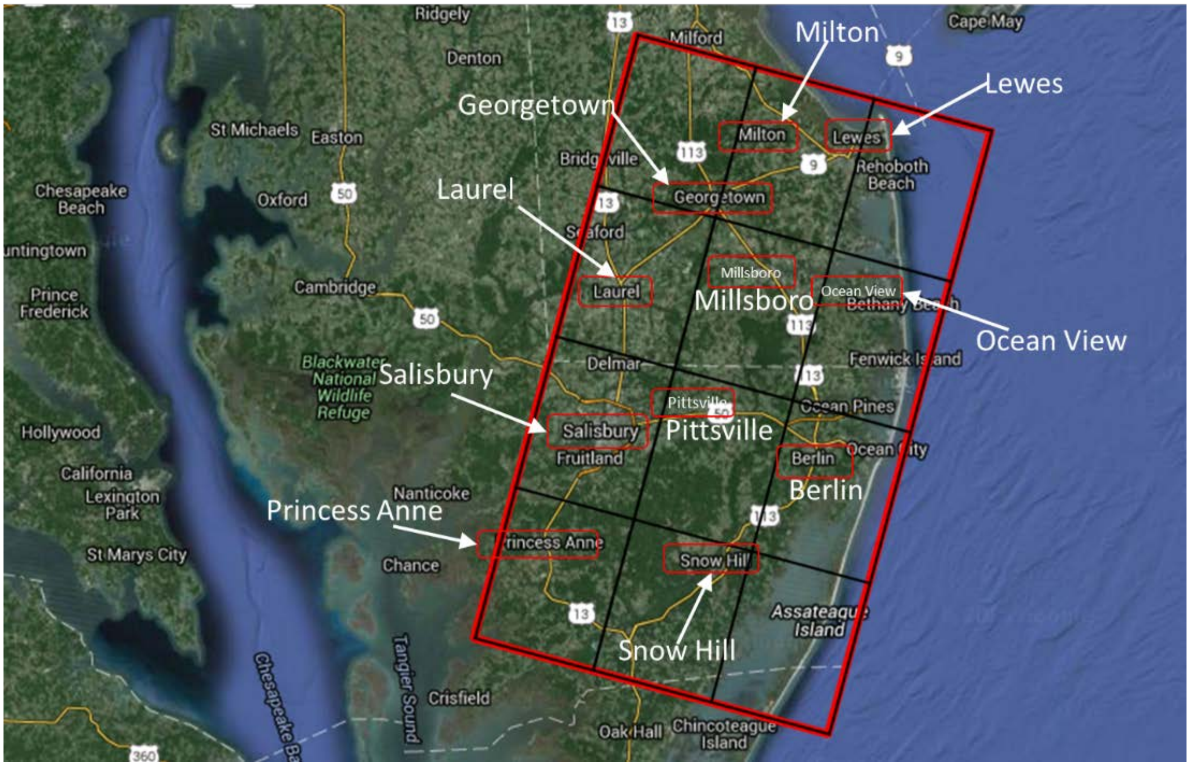


Figure 2-33 Identified Prominent Communities in Grid Cells, Mixed-Humid Region

Population

Princess Anne 3,290	Salisbury 30,343	Laurel 3,708	Georgetown 6,422
Snow Hill 2,103	Pittsville 1,417	Millsboro 3,877	Milton 2,576
n/a	Berlin 4,485	Ocean View 1,882	Lewes 2,747

% of Recruitment Area Population

Princess Anne 5.23	Salisbury 48.35	Laurel 5.89	Georgetown 10.20
Snow Hill 3.34	Pittsville 2.25	Millsboro 6.16	Milton 4.09
n/a	Berlin 7.13	Ocean View 2.99	Lewes 4.36

Recruits (600 Total)

Princess Anne 52	Salisbury 484	Laurel 59	Georgetown 102
Snow Hill 33	Pittsville 23	Millsboro 62	Milton 41
n/a	Berlin 71	Ocean View 30	Lewes 44

Targets Required (assuming 22% response)

Princess Anne 209	Salisbury 1934	Laurel 236	Georgetown 408
Snow Hill 134	Pittsville 90	Millsboro 246	Milton 164
n/a	Berlin 285	Ocean View 120	Lewes 175

Figure 2-34 Proportional Recruitment Targets, Mixed-Humid Region

Figure 2-35 Prominent Community Demographics, Mixed-Humid Region

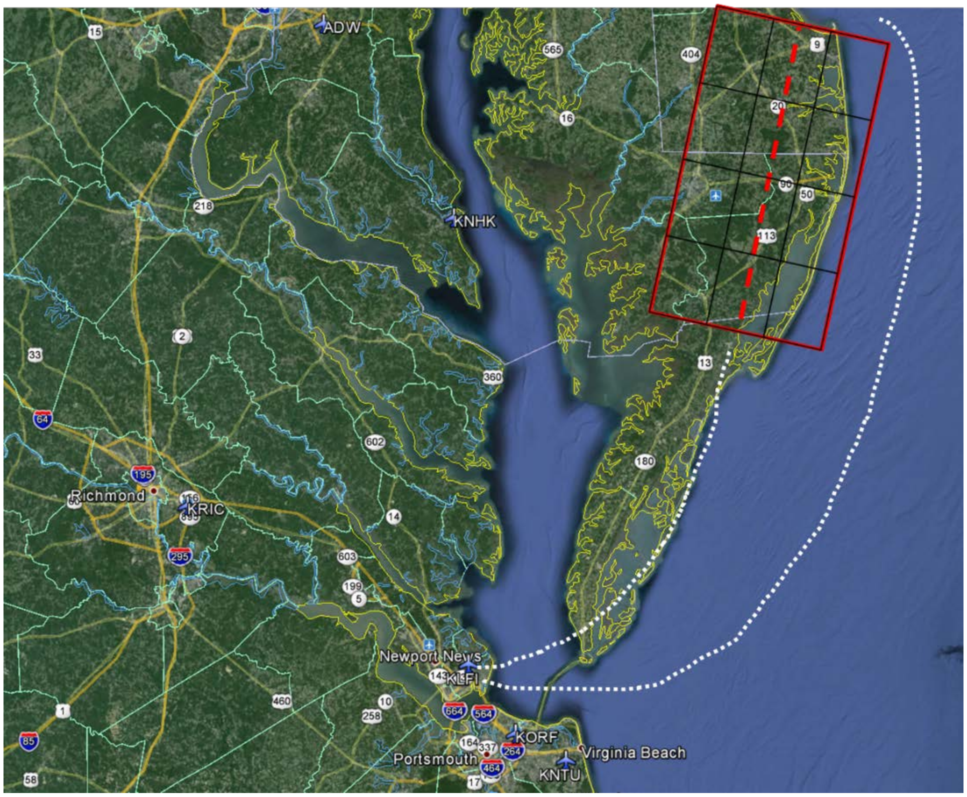


Figure 2-36 Potential Flight Track from Selected Base of Operations, Mixed-Humid Region

2.8.5 Hot-Dry Region – Southern CA – Edwards Air Force Base

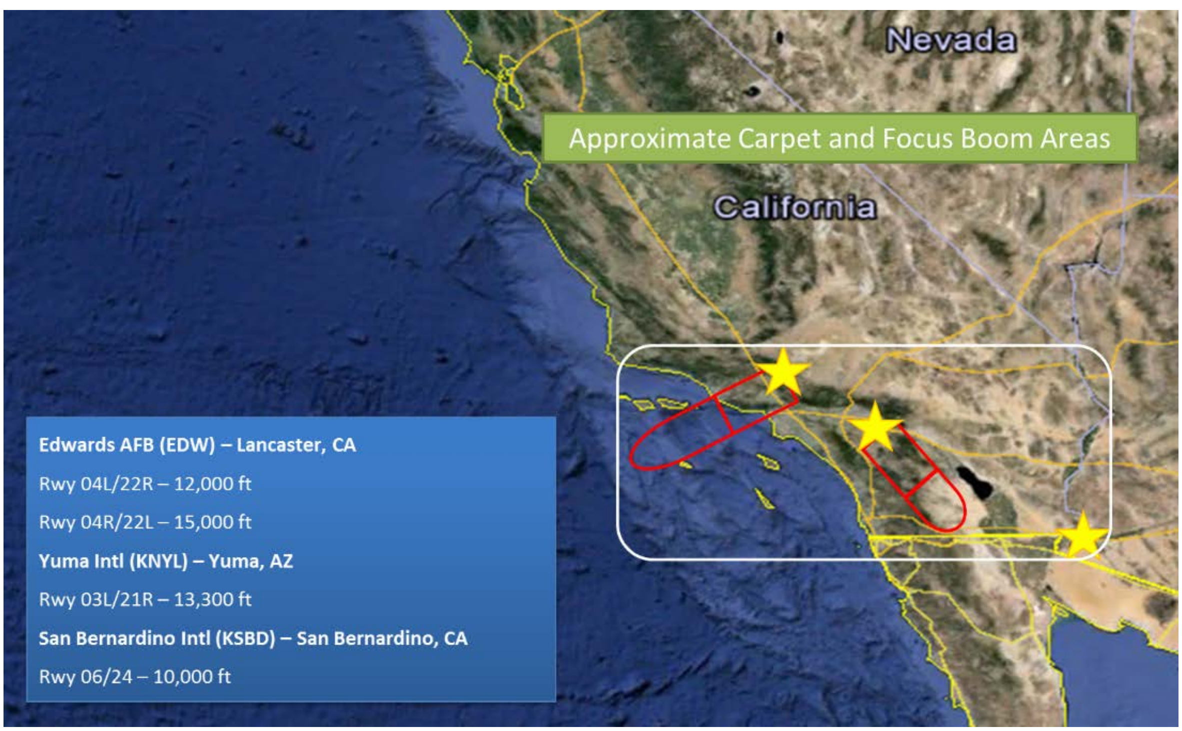


Figure 2-37 Potential Operational Sites – Hot-Dry Region

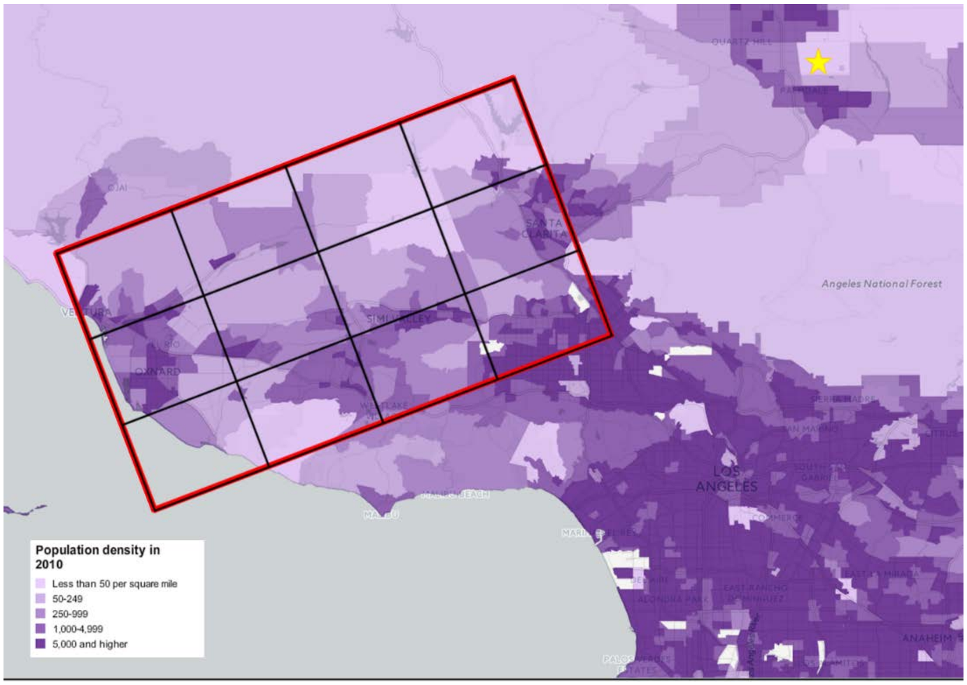


Figure 2-38 Community Selection / Population Density Grid, Hot-Dry Region

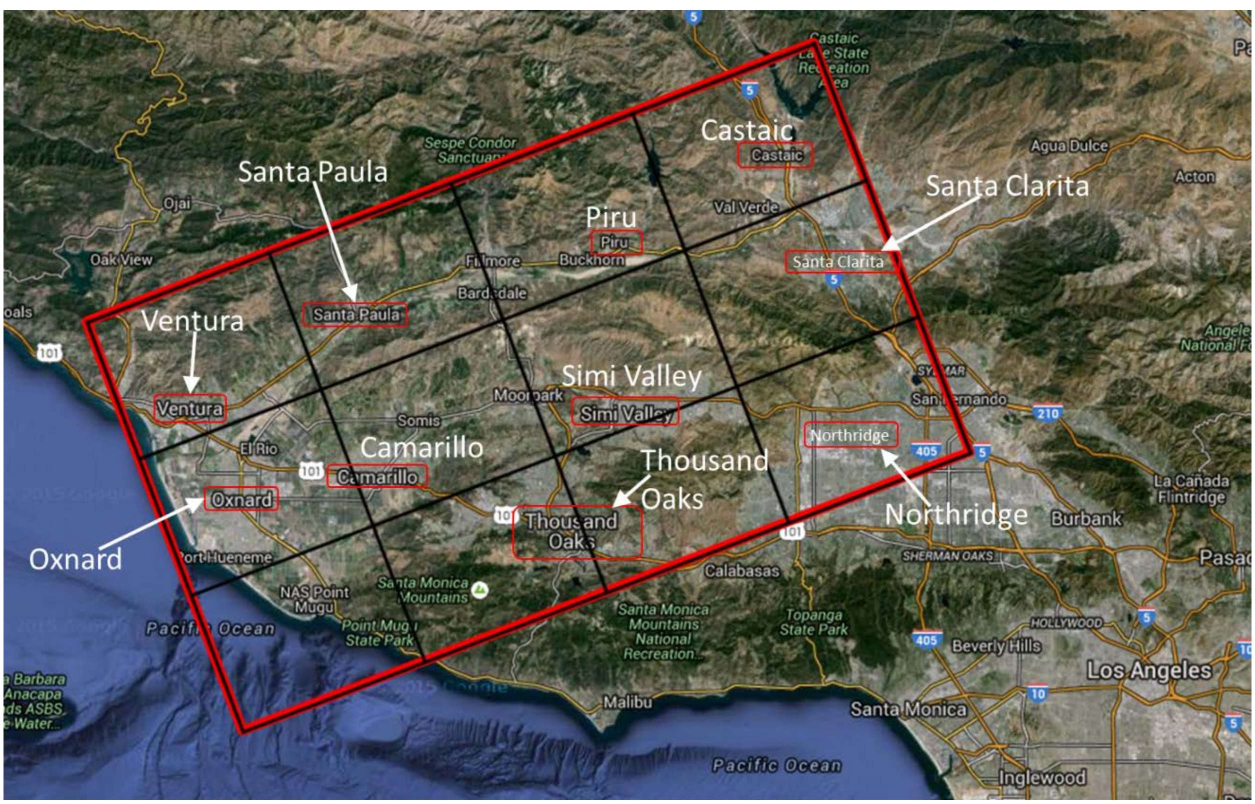


Figure 2-39 Identified Prominent Communities in Grid Cells, Hot-Dry Region

Population

Ventura 106,433	Santa Paula 29,321	Piru 2,063	Castaic 19,015
Oxnard 197,899	Camarillo 65,201	Simi Valley 124,237	Santa Clarita 176,320
n/a	Thousand Oaks 126,683		Northridge 61,993

% of Recruitment Area Population

Ventura 11.71	Santa Paula 3.23	Piru 0.23	Castaic 2.09
Oxnard 21.77	Camarillo 7.17	Simi Valley 13.66	Santa Clarita 19.39
n/a	Thousand Oaks 13.93		Northridge 6.82

Recruits (600 Total)

Ventura 117	Santa Paula 32	Piru 2	Castaic 21
Oxnard 218	Camarillo 72	Simi Valley 137	Santa Clarita 194
n/a	Thousand Oaks 139		Northridge 68

Targets Required (assuming 22% response)

Ventura 468	Santa Paula 129	Piru 9	Castaic 84
Oxnard 871	Camarillo 287	Simi Valley 547	Santa Clarita 776
n/a	Thousand Oaks 557		Northridge 273

Figure 2-40 Proportional Recruitment Targets, Hot-Dry Region

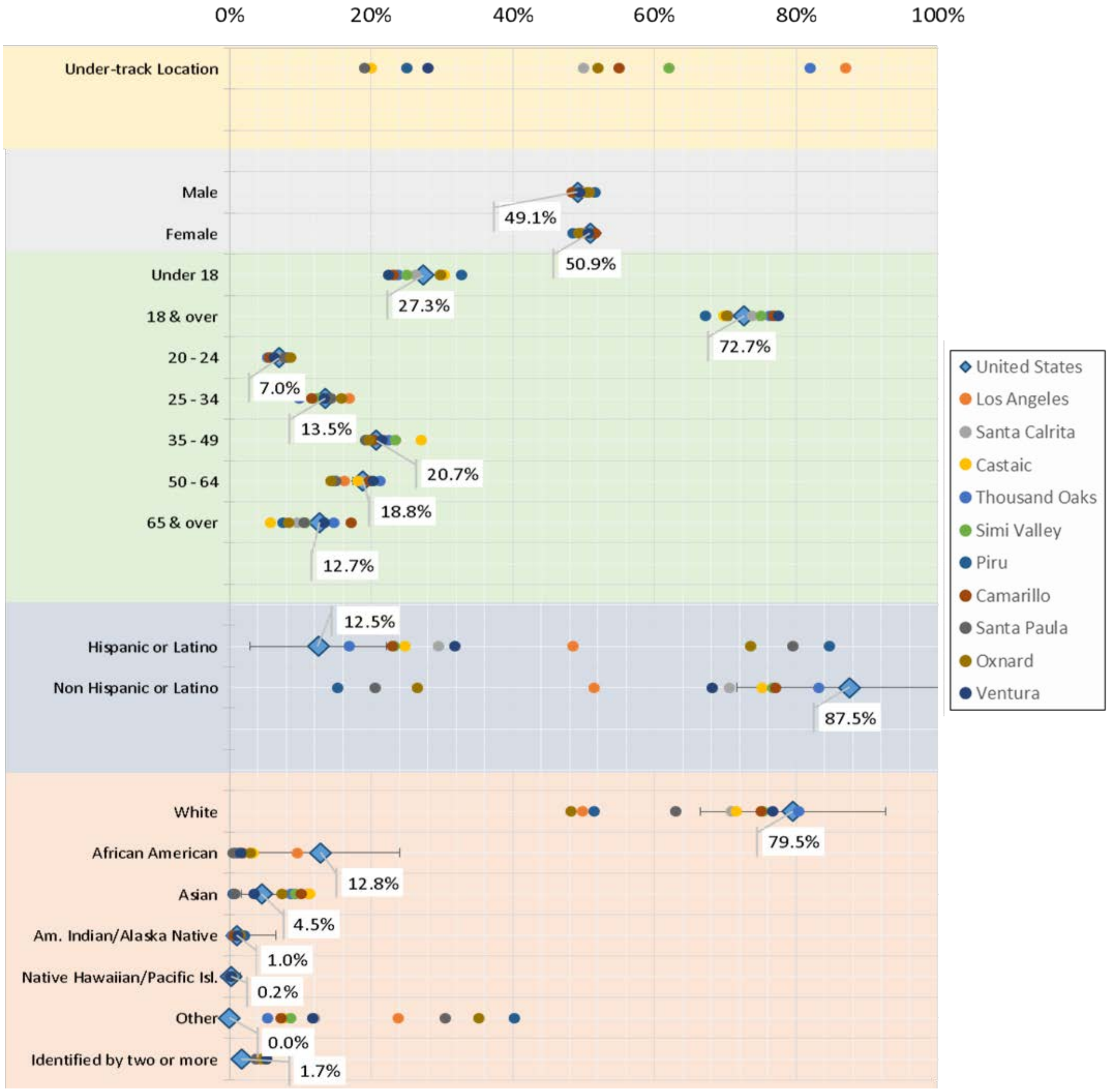


Figure 2-41 Prominent Community Demographics, Hot-Dry Region

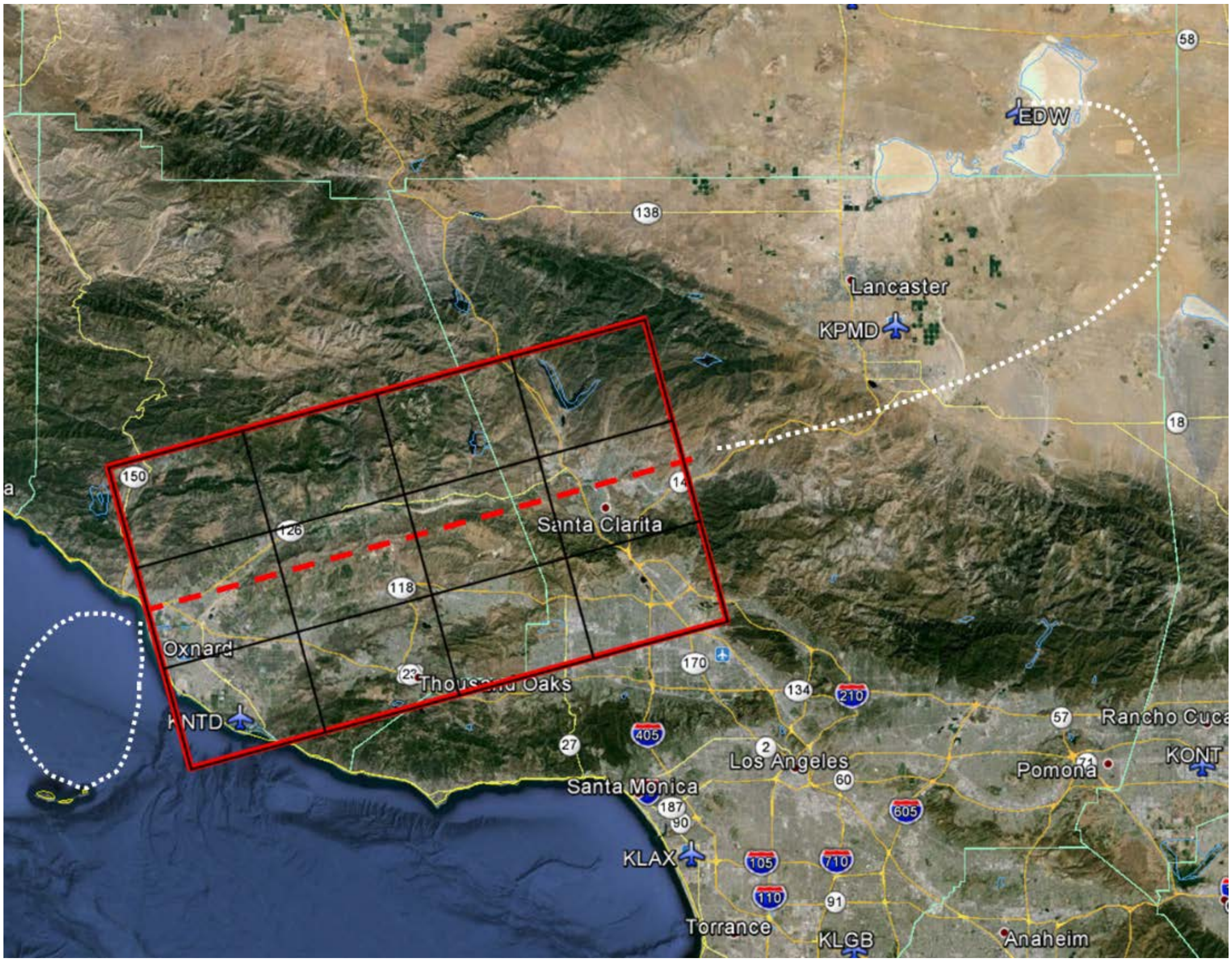


Figure 2-42 Potential Flight Track from Selected Base of Operations, Hot-Dry Region

3. Strategies for Communications

Aviation stakeholders and communities are engaged in a national dialog balancing how to advance aviation as an economic driver within communities while remaining committed to reducing environmental impacts, such as the impact of aviation noise on local communities. The WSPRRR team is conducting a federally funded research effort designed to demonstrate the future potential of supersonic aviation technology while conducting an assessment of community noise impact. Our team will contribute to that community based dialog as we implement the field test design. The approach implemented to engage with any one of the many communities that will be involved may directly influence an individual participant's reactions or community reaction as a whole, whether to the risk mitigation activities or future LBFD testing. That ongoing dialog was considered when the Outreach approach was determined. It was determined that a full scale media campaign was not as viable as a more subtle approach. The subtle approach was chosen in an attempt to minimize full media coverage until the test was conducted and to not influence or bias the test communities' response. This section presents our conceptual approach to community engagement and Outreach.

3.1 Outreach

Outreach includes engaging the public through information and interactive learning experiences in an environment that fosters public understanding through education. It is intended to educate and excite people about the current US Technological lead in the Civil Supersonics area, to share advanced technology and underlying concepts, acknowledge challenges, and to inspire students and travelers to imagine the future. The intent of Outreach for this effort is to educate and inform the public about the potential to have civilian supersonic flight over land with a lower boom noise impact and the science underlying those concepts. For many individuals, supersonic flight is associated with the special military operations and the Concorde, and louder booms. Outreach is intended to provide information on the newer technology that affords the potential for a lower boom having minimal impact on communities.

The WSPRRR team can conduct initial community based Outreach and implement Outreach in LBFD test communities. WSPRRR Outreach will be presented within participating communities, but there is also is a need for an exciting and inspirational nationwide supersonics outreach effort. A full National Outreach campaign is a sufficiently important element that it is recommended that additional funds be allocated to this as a separate project, or support of National Outreach be obtained separately from NASA and other funding agencies.

3.2 Consistent Approach across Sites

The WSPRRR Outreach team will consist of diverse agency membership that will include researchers from the WSPRR team as well as NASA and DOT representatives from Supersonics, Outreach and public affairs offices. The Interactional dynamics with NASA Outreach are yet to be determined, however, we plan to optimize NASA Outreach resources to conduct each community based effort. In Phase 2 a strategic approach will be finalized to implement our conceptual Outreach plan in each community. The WSPRRR Outreach team will develop content for briefing community leaders, media releases and general Outreach material. We will conduct Outreach in conjunction with NASA representatives.

The WSPRRR communications approach needs to be fairly standardized across communities, while incorporating information that is specific to each geographic location. To do this, the team needs to be aware of community infrastructure, local demographics, community specific government structure and forums, and any cultural norms that are unique to that region. Because English is the recognized language for the United States, the test plan currently requires English speaking participants. However, our team can accommodate a multi-lingual approach if required by NASA, or dictated by the diversity within a selected geographic region.

The team will seek to identify and work with leaders in local government and community organizations, which may include, but is not limited to local city, borough and township officials, relevant community organizations and emergency responders. Initially we will need to determine if any permits are required, although that is not likely. The initial contact will be with government officials to inform them about the plans for the upcoming research based test. Emergency responders would be informed of the upcoming test as a precaution, to afford them the appropriate informational response in the event that the sonic booms generated during the experiment prompt concern from residents. We plan to be aware of the unique aspects of each community and will identify community specific outreach opportunities to create content focus for individual communities as needed. We will implement an in depth educational outreach plan to execute across multiple communities as delineated in the following sections.

3.3 Community based Approach

The WSPRRR plan initiates a more subtle Outreach approach prior to the test, with a media based outreach effort after each Regional field test has been completed. If this were a demonstration of technology, the recommended Outreach approach would be to fully educate the community prior to testing. Because we are gathering data for regulatory review, we need to be cautious that our Outreach does not appear to influence the participants' response to the low booms. The proposed subtle approach is intended to limit the extent that respondents are biased by media discussion of the field test. This approach advocates maintaining a low profile initially to avoid large media coverage and the introduction of bias. The test objective is to gather data to support regulatory review, and the proposed design considers the potential impact of media coverage on our data gathering process and how our findings are viewed. Positive media coverage could bias respondents, and could also be misconstrued as an attempt by our team to bias research participants to respond more positively. Negative media coverage could bias our respondents, and could result in potential community based objections that could delay the flight test. As such, we are delaying full media coverage until after the test. The information provided initially will consist of research test based content. Additional detail concerning the rationale for this approach can be found in Appendix D.

3.4 Communications Contingency Plans Leveraging ASCENT

Researchers currently at Penn State, Volpe, Gulfstream and Wyle have teamed for the past several years on various low boom research efforts as part of the Partnership for Air Transportation Noise and Emissions Reduction (PARTNER), an FAA/NASA/TC sponsored Center of Excellence (COE). The PARTNER

Sonic boom team conducted research until 2013 under when that COE concluded. The PARTNER team of researchers expanded their team and subsequently formed the Aviation Sustainability Center (ASCENT), a new FAA sponsored Center of Excellence. The low boom research is being continued by this team of researchers through the ASCENT Supersonics Team. As part of the ASCENT sponsored Supersonics effort, researchers are investigating optimal approaches to monitor boom impact. One approach under investigation is the use of social media monitoring implemented in a form of pro-active Outreach. On-line observation of public domain comments will allow our team to quickly address concerns with a proactive press release, taking prompt action to contain any potential viral negative media.

Social media monitoring tools have been identified that allow monitoring to be conducted in a defined geographic area. The team would need to identify key words to monitor on select social media sites. The geographic area could be defined to include all communities under the flight path. This allows us to monitor responses on social media in areas where we may not have noise monitors or formal respondents. The comments on social media could provide insight into a reaction to a boom impact that we didn't anticipate. The monitoring of social media is the equivalent of a soft sensor implemented to alert us to extreme events (an unexpectedly loud boom impact) and to observe reactions within the community. The monitoring would be conducted over a one month period for each geographic site. Monitoring would begin one week before the test, continue throughout the field test, and for one week after the test. Monitoring the week before the test allows us to determine if there are any noise related issues within the community at the time of the test or if there is any pre-test on line discussion of our upcoming field test. Monitoring the area for a week following the test allows us to observe community comments. We can use this as feedback to better inform future new releases or outreach content. During the test, we will be using social media monitoring (SMM) to observe if there is any indication of a viral negative community response to the flight tests. We will have press releases and information available for immediate distribution if needed as the research progresses. In the event that concerns are observed within the community or through SMM, we can distribute press releases immediately that address those concerns.

Social media monitoring (SMM) will be utilized to seek and identify any indications of viral negative community response to the flight tests. Viral social media could be posted as a result of loud boom like noises outside the test area, unintended focus signatures impacting areas due to changing atmospheric conditions or someone responding from a water-borne location (i.e. boat) under the focal region. In the event that concerns are observed within the community or through SMM, the test plan calls for immediate distribution of press releases that address those specific concerns.

3.5 Communications Materials

During Phase 2 the team will develop informational content that is designed to enhance knowledge and raise awareness as part of the outreach working group mentioned in Section 3.2. The content will provide information on supersonic low boom related research. Outreach efforts will include multi-media and web-based education, public meetings formed in conjunction with FAA, local agencies and/or community groups, media based information and written publications including flyers, handouts, or pamphlets as appropriate. Content will be presented in a variety of formats in easy to read language, with written content associated with informative images. Content would be initially written using technical language to ensure accuracy, and then edited to simplify the reading level. A reading level of 8th to 10th grade will be targeted to match the national reading level. Some content may not lend itself readily to a 10th grade reading level. Accuracy would be maintained, and the content would be simplified as much as possible. Relevant video links would be identified to provide multi-media learning opportunities. The team will implement the PLAIN language approach as required by the Plain Writing Act of 2010 (Public Law 111-274), http://www.plainlanguage.gov/.

Outreach typically provides background educational information. We will implement a multi-method delivery approach using both NASA and FAA Outreach resources, to more fully educate the public. The FAA sponsored ASCENT NoiseQuest site (www.noisequest.psu.edu) has been established for general educational purposes on noise, including low boom topics, and is not available as a means to communicate directly with the communities about the NASA tests. NoiseQuest is a recognized FAA support Outreach site that is available as an existing educational outlet. The site is a global resource for both airports and communities that provides information on aviation noise, as well as outreach components, metrics and models, and aviation noise information. In 2015, the site had 28,446 global session and 15,229 sessions across the United States. The two maps below show the sessions in 2015 by US city and by city globally.

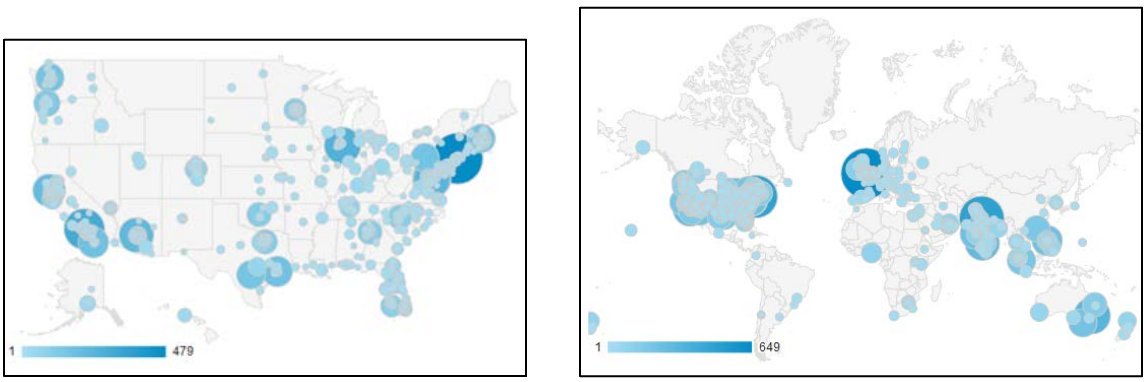


Figure 3-1 Noise Quest Sessions by US Cities (Left) and in cities across the globe (right)

Table 3-1 NoiseQuest sessions Top 10 US Cities (Left) and by country (right)

Top 10 Cities In US	Sessions	Pages/ Session
New York	479 (3.15%)	2.27
Los Angeles	296 (1.94%)	2.62
Washington	270 (1.77%)	3.02
(not set)	269 (1.77%)	1.64
Chicago	256 (1.68%)	2.00
Alexandria	240 (1.58%)	2.10
Phoenix	219 (1.44%)	2.15
San Francisco	198 (1.30%)	1.75
Houston	188 (1.23%)	1.65
San Diego	170 (1.12%)	2.49

Sessions in 2015 by Country	28,446 % of Total: 100.00% (28,446)
1. United States	15,229 (53.54%)
2. United Kingdom	2,168 (7.62%)
3. India	2,025 (7.12%)
4. Canada	1,294 (4.55%)
5. Australia	934 (3.28%)
6. Philippines	670 (2.36%)
7. Kenya	312 (1.10%)
8. Singapore	291 (1.02%)
9. Malaysia	277 (0.97%)
10. Netherlands	263 (0.92%)

NoiseQuest is an aviation resource that was developed to implement global education and outreach on aviation noise topics. The site statistics (Table 3-1 and Table 3-2) show that the NoiseQuest is an international resource, and that users span the range of computer domains, coming in to NoiseQuest from education, government, industry, military, airlines, airports, and public domains, as well as from other countries.

Our findings will be presented to a global audience through these websites. The content placed on the these sites will be research based, reporting on the conduct of the test and the subsequent test findings. We will present the information to demonstrate advances in technology that could shape the future of aviation. We will be selective in how we present our findings, again to prevent the perception of bias. The team also plans to finalize an Outreach approach that includes utilizing individuals identified at NASA that would also conduct Outreach for this effort. The final Outreach plan will identify how best to optimize their expertise and NASA Outreach resources.

We will also develop presentations and posters that will be available as downloadable pdfs from NoiseQuest for community groups or teachers to use as classroom content. We plan to use the Gulfstream Sonic Boom Acoustic Signature Simulator (SASSII) for auditory familiarization and hands on education.

3.6 Pre-Test Community Engagement and Outreach

The team is evaluating several options for pre-test engagement. One option under consideration is to assess local noise attitudes through social media monitoring to determine whether a selected community is already experiencing any local noise-related issues. For example, monitoring social media in advance of any testing may provide additional perspective on existing noise concerns and help identify any preconceived bias within the test community.

If there is a current aviation noise lawsuit in the area, we may choose to recruit from a different location. The information can provide a context if the findings are inconsistent with other areas.

We plan to conduct an orientation effort using the Gulfstream Aerospace SASSII simulator [Salamone *et al.*, 2005] to introduce respondents to the sound character of a low boom and train them on the range of low booms to be presented. Familiarization with the sound character and potential levels of low boom events will help respondents to better recognize booms, and distinguish them from other similar sounds. Research based materials would be developed for this Simulator Days familiarization period, to introduce the concepts behind the field test. This would include descriptors such as comparing the low boom noise to distant thunder or two car door slams in succession. The team would need to keep a record of which participants heard the range of booms in the simulator. Our approach would not widely advertise the familiarization period, but it would allow any interested parties to join in. This affords the opportunity to provide auditory exposure and training to allow the respondents to identify sound character and range of booms.

Pre-test community engagement for local government officials and respondents, will present information specific to the research test, such as instructions, sound characterization and familiarization and the purpose of the study. After the test, the team will implement a full outreach effort for all residents within the test area, as described above. The team will identify News Media outlets that are both traditional and web-based. This would include print, TV, radio, web-based, and newsletters. Communities may already have established community announcement outlets (TV, radio etc.) that can be utilized for media releases after the completion of the social survey field test. This approach is being implemented to limit the extent that media coverage could bias the respondent’s perspective.

3.7 Post-Test Outreach

General Outreach information will be distributed across the community after the research test is completed. We acknowledge that this information will be distributed beyond the test community, on a global scale. We will indicate in press releases at that time that future tests will be conducted to verify the results of our findings from the first community, in a location yet to be determined. In subsequent communities, we will still implement as subtle of a pre-test presence as possible, but will address any issues raised by pre-existing media coverage. We acknowledge that media coverage could bias our subsequent field tests. We are taking every precaution possible to ensure that our actions entering a community do not prompt media coverage, either positive or negative, that could raise a question of our biasing the respondents, and potentially cast doubt on the integrity of our research findings. A “pre-emptive” media release could be viewed as causing bias in the participants’ responses. Because we are gathering data for regulatory review, our process is held to a greater level of stringency than if we were conducting a technology demonstration and basic research. Additional detail concerning this approach can be found in Appendix D. We are cognizant that this test is being conducted for regulatory review, and as such, are taking additional precautions with our Outreach planning and the conduct of our Outreach efforts to ensure the validity of our research findings.

BLOODHOUND Project (http://www.bloodhoundssc.com) was reviewed as an example of an innovative Outreach approach for science and technology. It is an Open Data global engineering effort in which the research, data, designs and ongoing progress are available on line. Its goal is to set a new World land speed record by creating the first 1000 mph car, while simultaneously inspiring the next generation of scientists and engineers. The project was launched publicly on October 28th 2008 at the Science Museum in London. The Open Data effort enables academics, students and others to capitalize on the unparalleled access BLOODHOUND SSC offers to a live advanced STEM project. The project includes educational information and opportunities for students from K through 12 and at the university level. Students, teachers, researcher and interested members of the public can access engineering data on the development of the car. The design data, test data and run data will be available on line from actual car runs. The team is instilling excitement for science through the development of this new technology. The inspirational approach to education can be modeled in a global Civilian Supersonic Flight Outreach effort.

The Outreach approach for WSPRRR is not as large scale as the Bloodhound SCC project. The parallels are that the WSPRRR project does have the potential to instill excitement about the future of supersonics by presenting this new application of the existing supersonic aviation capability. The Outreach effort can educate the public and present information on the potential for civilian supersonic flight over land. The WSPRRR Outreach effort needs to counter pre-conceived notion that supersonic booms are all loud based on past observations of military aircraft and the Concorde. The Outreach effort will seek to educate the public, present information without presenting bias and maintain a research based perspective and approach.

4. Subjective Design

4.1 Overall Concept

The assessment of community noise impact from civilian supersonic flight over land from a low boom flight demonstrator vehicle requires a flight research campaign to investigate the relevant objective and subjective variables that affect the given noise environment. Subjectively, it should assess aspects of community impact including annoyance, attitudes, and the extent to which the noise interferes with daily activities. Objectively, it should adequately measure the noise environment and identify an appropriate metric to represent it. Details concerning the technologies required to support these measurements are presented in section 6.4.1. Correlations between objective and subjective variables can identify methods and metrics that relate to the subjective perception. The findings of such research could contribute to the development of federal policies.

4.2 Survey Development

The focus of the survey design and implementation task is to develop and utilize a survey instrument to discern the relationship between noise metrics and any resultant community annoyance response from low boom noise. Survey materials from previously tested WSPR instruments will be leveraged to the greatest extent possible, but may require some modification in advance of testing. Survey templates are presented in Appendix C. The surveys will be tested and finalized in Phase 2.

The survey must include key features that can help to distinguish these responses to noise by assessing the appropriate contributing variables. The purpose of survey research is to better understand the perspective of a given individual within a community, and to see how that individual compares to other members of the community. The individual's perspective is predicated by their own psycho-physical features, their past experiences and their personal viewpoints. Beneath those variables, community residents respond in certain basic fundamental ways, and there is comparability between individuals. The construct of the survey instrument is intended to glean these attributes and features in a manner that allows for comparisons of a given individual's response to different situations and to afford comparisons between different individuals. We recognize that there may be Spanish only speaking residents within our research communities, as reflected in the US wide population. Since the US has not legally identified Spanish as a second primary language we have not included a Spanish translation of the survey, bi-lingual execution of the survey administration, or statistical comparative analysis across languages. However, our team does have access to this expertise and can incorporate this into the project if necessary.

Survey questionnaires are designed to support a range of noise responses as well as the contextual variables or housing characteristics that may alter response. By including a range of response variables (e.g., measures of loudness, intrusiveness) as well as annoyance ratings, subjective data analysis will be better able to detect variation, or demonstrate consistency, in response ratings. The recommendations of the International Commission on the Biological Effects of Noise (ICBEN) guidelines [Fields *et al.,* 2001] for conducting noise surveys will be utilized in the survey design. The ICBEN guidelines utilize a set of standard descriptors to facilitate the ability to compare research findings from different institutions in different countries. The survey will be based on prior social surveys used in Strategic Environmental Research and Development Program (SERDP) sponsored Army field assessments of blast noise and the NASA sponsored WSPR test of low boom noise. Researchers on this team utilized ICBEN fundamentals while conducting these prior socio-acoustic surveys. The survey instrument will be prepared based on recent experience with these NASA [Page *et al.,* 2014] and SERDP [Pater *et al.,* 2007] noise survey programs. The research design in each of those programs followed recommendations for survey development and implementation as indicated in Fields [2001] and as represented in ISO/TS 15666 [ISO, 2003].

The survey format and questions will be similar to these previously evaluated surveys. As implemented in these two community surveys, we anticipate that the Single Event and Daily Summary (EOD) surveys will include a question on strength of annoyance, followed by questions on the strength of perception of additional categorical variables, such as loudness, that contribute to the annoyance response. The questions will gather data on multiple dimensions of subjective response to noise. The potential variables listed below provide categories that could be used as input variables in the data analysis. The survey would contain the primary response variables and a subset of other variables (Table 4-1).

Table 4-1 Subjective Design Response Variables

Response Variables
Primary Response Variable: Annoyance variables with respect to relevant type of noise and categorical attributes that contribute to annoyance such as loudness, intrusiveness or vibration.
Demographic Variables: Age; Gender; Occupation; Years of education; Duration of residence at present address; Household composition; Household income range; Occupation; Years at current employer
Construction Category: for house and/or workplace: size and type such as: single dwelling, duplex, apartment, office building, high rise, box store, strip mall, etc.
Attitudes: Attitude towards neighborhood; Annoyance with respect to different types of noise sources; Annoyance with respect to traffic noise, helicopter, aircraft noise; Perceived ability to habituate to noise
Noise Sensitivity Factors: How often do you notice the noise? Do you find yourself listening to the noise? Do you think you are more sensitive than others are to noise?
Contextual Factors: Time spent at/away from home; Times typical for waking up and going to bed; does the noise interfere with communications or other activities?

The noise source that is primary for this community impact survey is supersonic low boom aviation noise. The primary questions will obtain respondent specific ratings of their individual annoyance response. Other questions will assess contributing features that define the respondents' experience. By including a range of measures as well as annoyance ratings, the subjective data will be better able to detect variation and to demonstrate consistency in the responses obtained from the participants. The survey questionnaires will replicate standard and key measures of previous studies to facilitate comparison with other research findings.

Survey instruments are greatly varied in how they are structured to attain the desired information. The instruments vary on the mode of administration, the methods employed during the conduct of the survey, the length of the survey, the question format, the response format, the primary variables that are assessed, the contributing or moderating variables that are included and the planned method of analysis. It is important to consider the anticipated duration of the survey and the respondent burden when constructing the survey instrument. This is a critical component evaluated in the OMB review.

4.3 Survey Implementation

We have chosen to use a web based survey implementation utilizing smart phones, iPads, laptops as the response mechanism. If necessary we can include a respondent with paper/pencil response, but we would prefer to recruit web based respondents. We are implementing multiple survey formats as described in Figure 4-1. Once the respondents are recruited, they will be provided with background information and fully informed as to the test design as part of the informed consent. The language will include the research sponsor, the purpose of the research and what we are asking the respondent to do.

Sample of language excerpt from Informed Consent:

Researchers sponsored by the National Aeronautics and Space Administration (NASA) are conducting research on people's attitudes about aircraft noise in their communities. Developments in aircraft design and scientific research indicate the possibility of softening the sonic boom noise associated with supersonic flight. NASA has developed a method for generating sonic boom noise similar to that anticipated for quiet supersonic flight. We need your help to understand how individuals experience this noise in their homes, neighborhoods and work place.

- *We are looking for volunteers to take part in a study about sonic boom noise in your neighborhood. Participants will be asked to complete a brief set of questions each time they hear a sonic boom over a few weeks. To be eligible, participants should be 18 years of age or older*
- *live and work in an area under the planned flight path*
- *Prefer that participants have web or mobile device for survey responses*

Participation is voluntary and survey responses will be confidential. The information provided will be used for statistical purposes and will not be reported in a way that would reveal individual participants.

Figure 4-1 Sample of Language from Informed Consent

4.3.1 Contact Survey

We are using addressed based sampling to initiate our recruitment as described in Section 7. Once respondents are identified we intend to primarily use a web-based survey implementation. In the initial contact with potential respondents, a contact survey link will be included to a URL where they can sign up to participate in the survey. The contact survey will ask for on-line contact information (email and mobile phone), seek consent to contact them via phone or email, and ask them to provide home and work address to ensure respondents both lives and works within the expected boom carpet. Seeking permission to contact the respondent by phone complies with The Telephone Consumer Protection Act (TCPA, July 2015). Those who complete the online contact survey will be mailed baseline survey via USPS which includes a printed baseline survey with a business reply envelope and a cover letter urging them to complete the survey on line at the baseline survey URL. This approach affords potential participation via paper/pencil, with a clear indication that our preferred response method is via web based applications.

4.3.2 Baseline Survey

The baseline survey will be a representation of the baseline survey previously tested in the WSPR program. A few questions will be added to clearly identify home and work locations to ensure that the respondent will be under the flight path. The survey questionnaire will be programmed in both printed booklet format, using Cardiff Teleform for scannable surveys, as well as being formatted in Qualtrics, a mobile enabled web based survey software platform. We will indicate our preference that the survey be completed on line. The survey length will be up to 40 questions (12 pages), which encompasses the length of the previously tested baseline survey.

4.3.3 Single Event Survey

The Single Event survey will be a mobile enabled web survey programmed into the PSU Survey Research Center's (SRC) Qualtrics survey platform. The questions on the Single Event survey will be patterned after the previously tested WSPR single event survey. Each morning, on the days an event is to take place an email will be sent to participants who have provided a valid e-mail address. The email will contain a link to the survey and instructions reminding them to respond to the survey throughout the day, to answer a few short questions if they hear a boom.

We will include the use of text push messages that state: "Please remember to listen for a boom" to encourage attentive listening. There will be instances where we will present a boom within 30 minutes, and other times we will send the text reminder with no subsequent boom. This design allows us to assess if the response is due to the text prompt or because the respondent heard a boom. The text prompt is included in the design in an attempt to address concerns about non-response. A non-response would occur if a respondent truly didn't hear a boom (not loud enough) or if they weren't listening (not responsive). Another alternative is to send a post-boom text that asks "Did you hear a boom?" This approach relies on the respondent's memory recall of the past 30 minutes. With this approach, there is a potential risk of mistaken recall. We would prefer to prompt attentive listening, than rely on memory recall. We can conduct a comparison test of the two approaches in the Risk Reduction test.

Reminders will be sent by text and e-mail to those who have not completed the single event survey within a predetermined period of time.

Any text messaging that takes place will need to conform to the FCC's Telephone Consumer Protection Act (TCPA). This includes that consent to text must:

- Be in writing
- Come from the owner of the device where texts will be received
- Identify any parties that will have access to the respondent phone number
- Make clear the type of messages that will be sent
- State the costs or potential cost to the respondents
- Include information on how to opt out of the messaging

4.3.4 End of Day (EOD) Daily summary survey

An End of Day (EOD) Daily summary survey will be programmed into the mobile enabled web SRC's survey platform. The EOD format will pattern the EOD/Daily Summary survey previously tested in WSPR. The data will be time stamped. At the end of the day an EOD survey link will be sent to respondent's e-mail address, reminding them to complete the EOD survey. If they have not completed by a certain time frame (1 hour) they will be sent a reminder. Those who do not complete within a reasonable time frame after the reminder (4 hours) will be considered out of compliance with completion on that day and be marked locked out of the specific EOD survey so that they cannot complete it on a subsequent day. They will be still be eligible to continue in the study and will be sent a notification for the next survey. Respondents who complete an agreed upon percentage of all surveys will be eligible for a $25 incentive for each week of completion for a period of up to two weeks. The goal is to encourage participation with a small financial incentive, while being realistic about participant availability. The required completion rate to receive compensation may be based on the cumulative daily response rates to avoid situations in which the boom was presented but not perceived. In the future, we have the ability to add an End of Night Survey if night time flights are included. If the respondent does not complete EOD within 1-hour, they will receive a follow-up reminder.

Qualtrics Geo-location Software

We plan to use a feature of Qualtrics™ which provides the latitude and longitude position of a participant responding through the Qualtrics survey app on a GPS-enabled device. The Penn State University Survey Research Center (SRC) has developed a simple prototype survey to determine the extent to which we can determine a participant's location when they respond to a single event survey (See Figure 4-1) utilizing the Qualtrics application. In compliance with IRB requirements, the respondent will need to consent to have this feature enabled. The informed consent and instructions will ensure that locations services are enabled on their mobile device and that they allow their location to be retrieved and sent through the mobile survey application.

Penn State University Survey Research Center (SRC) has developed a simple prototype survey to determine the extent to which we can determine a participant's location when they respond to a single event survey (Figure 4-2). This prototype utilizes a web app developed by Qualtrics™ which provides the latitude and longitude position of a participant responding through the Qualtrics survey app on a GPS-enabled device. In compliance with IRB requirements, the respondent will need to consent to have this feature enabled. The informed consent and instructions will ensure that locations services are enabled on their mobile device and that they allow their location to be retrieved and sent through the mobile survey application.

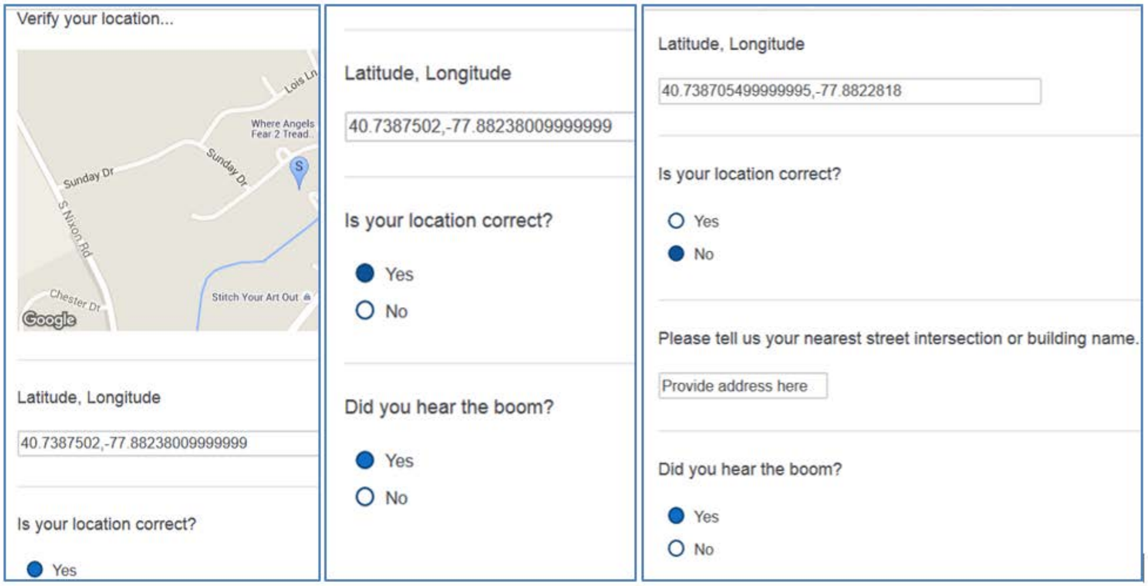


Figure 4-2 Geo-location survey implementation

The data provided includes columns that show the longitude and latitude of the respondent. If they are unwilling to use this we can still get valuable data from their survey responses, by asking them to provide the address from which they are responding. For participants taking the survey using the Qualtrics Surveys app on a GPS-enabled device, Location Accuracy represents a radius in meters from the reported longitude and latitude in which the participant may be located. A larger number indicates a less accurate location.

If the respondent does not have a GPS-enabled device, the survey app will identify a location that is an approximation determined by comparing the participant's IP address to a location database. Inside the United States, this data is typically accurate to the city level. Where location is approximated, the longitude and latitude presented are of the geographic center of the most accurate location available for the respondent.

Our team successfully tested iPhones, androids, iPads, and laptops. As shown in Figure 4-3 the survey provides a map of the respondent's location. The survey asks if the location is correct. If the respondent replies "Yes", the latitude and longitude are used as the location. If the respondent replies "No" the application presents a query that states: "Please tell us your nearest street intersection or building name", followed by a box for the respondent to type their address.

With some of the networked laptops at Penn State, the location provided was the geographic center of the area. We need to investigate further to see what the issues were with location services for those networked computers. We propose further testing to quantify the accuracy of the geo-location function during Phase 2. As stated in Section 4.3, this needs to include device, carrier, and other appropriate variables. We will leverage ASCENT support in conducting this additional testing in Phase 2.

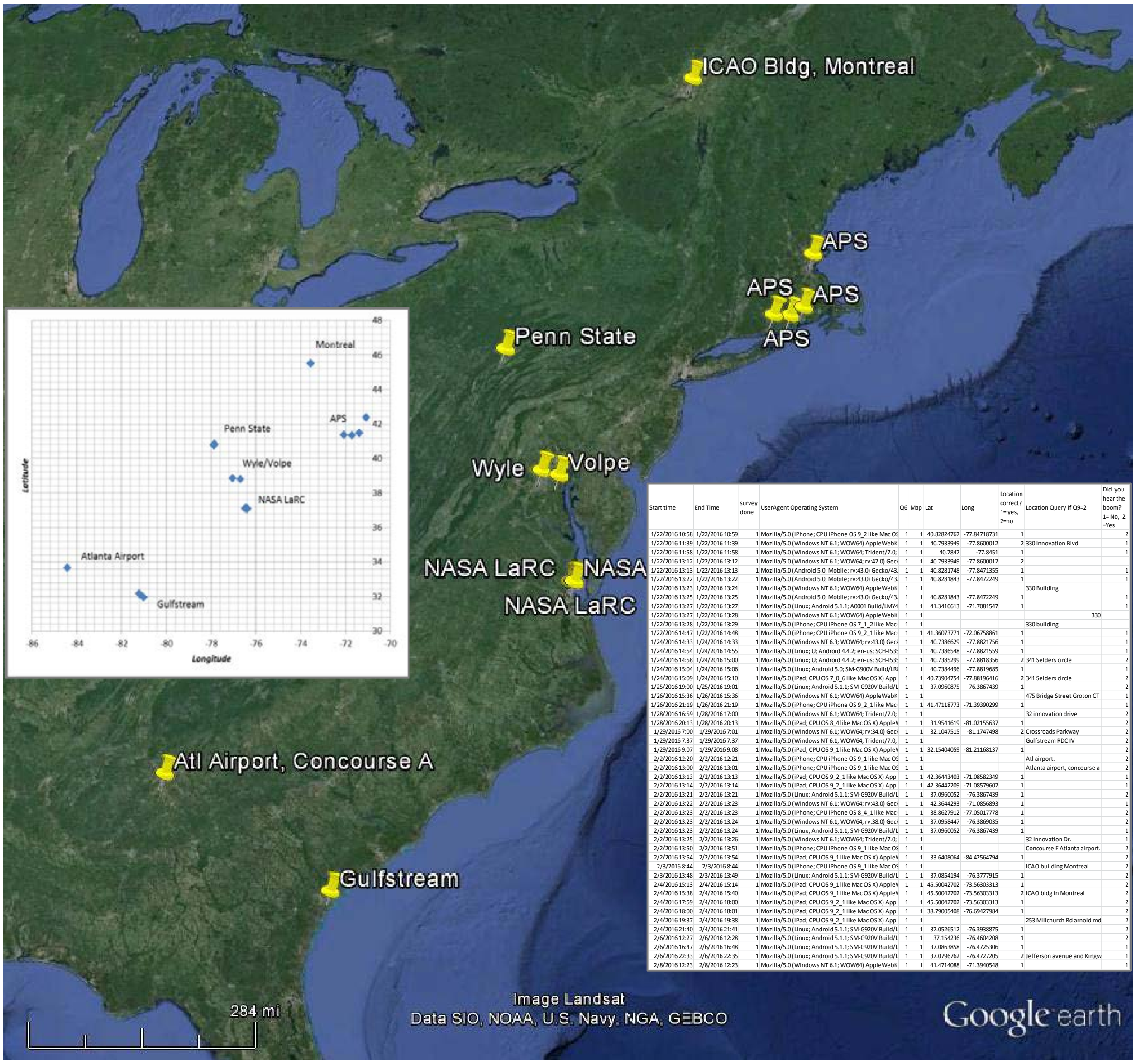


Figure 4-3 WSPRRR Team GeoLocation Testing During Phase 1

4.4 Data merging

All data source will be merged into a single data set that will allow for detailed analysis on a daily basis, additional details concerning the availability of objective measurement data is addressed in Section 6.1.3. In accordance with IRB requirements, all personally identifiable information will be removed from the data. The data will be stripped of information such as names, addresses, e-mail address, etc., and will be linked by the case ID provided for each sample member. The subsequent data analysis will be related to the case ID number. Merging of the objective data collected is addressed in Section 6.1.3.

4.5 Note on all web based data collection

All data collected using the mobile enabled web surveys will include time stamps and approximate geographic coordinates. This will assist in determining if respondent were in the presence of a boom when it occurred. The geographic coordinates associated with mobile devices or e-mail addresses may vary slightly by carrier and mobile device.

4.6 Institutional and Federal Regulatory Compliance

For the LBFD dose-response testing with the general public in the United States, both Institutional Review Board (IRB) oversight and Federal Office of Management and Budget (OMB) will be necessary. The majority of our proposed design is standard for noise survey research and research precedents will be identified. We will need to justify the rationale for including an estimation of the respondents' location in the survey data gathered.

A series of reviews with NASA and the PSU review boards were conducted during the development of the WSPR 2011 experimental design. A protocol was established between the Penn State IRB and the NASA IRB. The process proposed by the WSPRRR team will closely parallel that of the WSPR process for IRB reviews.

In preparation for non-acclimated community testing and gathering of subjective response data to low-amplitude sonic booms, we will also prepare a federal Office of Management and Budget (OMB) Application. The WSPRR team will prepare the OMB package. NASA has indicated that they will take the lead on submission of the application to OMB.

4.6.1 PSU Office Research Protections Institutional Review Board mandatory training

Any researcher conducting research involving human participants, who intends to be included on research publications, regardless of their direct contact with participating respondents, is required to complete IRB training. Training is valid for three years. To be included on the PSU IRB team, a PSU individual needs to activate the list of the team of researchers. The IRB information can be found at: http://www.research.psu.edu/orp/humans.

An individual can also complete training directly on the CITI program site, by setting up an account, indicating a research affiliation with PSU, and completing the training. https://www.citiprogram.org/

4.6.2 OMB Package Preparation and Submission

The Paperwork Reduction Act (PRA) of 1995 requires that OMB approve each collection of information by a Federal agency before it can be implemented. The information requested is intended to ensure that agencies employ effective survey and statistical methodologies that are appropriate for the type of information that is to be collected. The following information is required to be included in the OMB package:

1. Need for the Information Collection;
2. Use of this Information;
3. Detailed description set of questions, rationale;

4. Were the questions approved under prior approval number;
5. Efforts to Identify Duplication;
6. Burden on Small Business;
7. Consequences of Not Collecting the Information;
8. Special Circumstances;
9. Consultation and Public Comments;
10. Payments to Respondents;
11. Assurance of Confidentiality;
12. Sensitive Questions;
13. Burden hours to respondents;
14. Number of respondents, Number of responses per respondent;
15. Cost to Respondent (based on average hourly rate);
16. Cost to the Federal Government;
17. Publication of Results;
18. Procedures for the Collection of Information;
19. Information Analysis and Statistical correlations; and
20. Use of Information.

5. Objective Design

5.1 Design Concept

The dose response design will present a range of low boom levels that will be evaluated with respect to the subjective response obtained from survey participants. The anticipated range is from 70 to 85 PLdB under the flight track if off design booms are also included. The noise design will include single event noise doses that will provide the data to evaluate metrics for the noise certification process as well as for single event community impact. The cumulative daily noise exposure represents a sum of the single event exposures for each test day. The cumulative noise exposure data will be used to evaluate cumulative metrics that are comparable to existing aviation noise community impact metrics. The overall design will identify a range of daily exposures and replicate them over the course of the test period.

5.2 Noise Dose Design

The noise dose design for the LBFD Regional Testing will parallel the design that was implemented for the WSPR test effort. It consists of a range of boom levels that will be achieved by flying the LBFD in both on design and off design conditions so that a range of noise doses can be evaluated by participants. The final noise exposure design will attempt to balance DNL exposure across test days, as well as balancing the relative number low, medium, and high booms across the design. A wider range of noise doses affords an assessment of both on and off design boom impact. The anticipated noise dose varies as a function of location under the flight path.

Current LBFD designs indicate a range in loudness levels (PLdB) across the flight carpet [Ordaz *et al.,* 2015, Morgenstern *et al.,* 2012] with peak loudness in the sideline cells, however this is subject to change pending the final LBFD vehicle design (Figure 5-1).

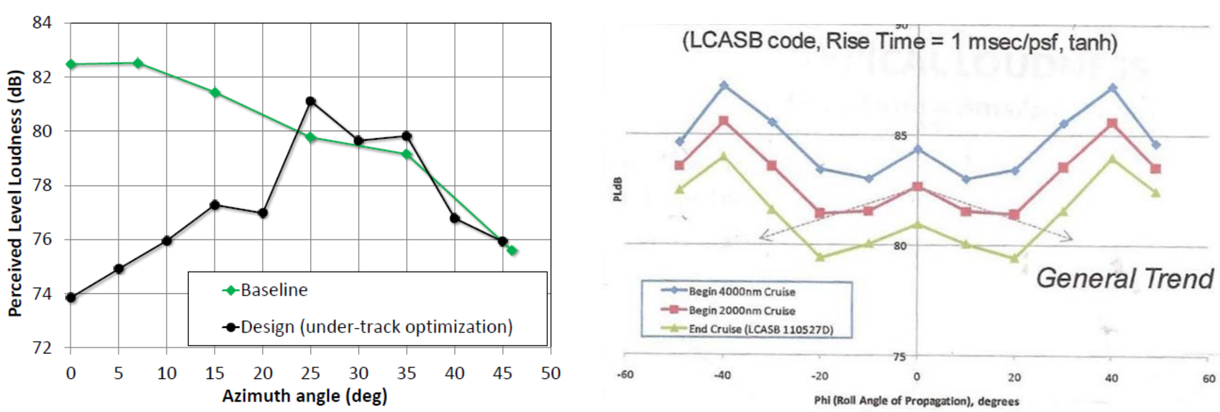


Figure 5-1 Range of loudness levels across low-boom carpet regions

NASA & Lockheed Designs Sources: [Ordaz et al., 2012] and [Morgenstern et al., 2012] respectively.

The noise impact directly under the track is anticipated at approximately 75 PLdB, with off-track levels anticipated at approximately 70-75 PLdB. In off design conditions it may be possible to present a level as high as 85 PLdB. The noise dose will identify single-event levels, number of booms per day, times of day, and number of test days for the sonic boom exposure. Current subsonic noise certification levels are based on single-event metrics. As such the test has been designed to evaluate both single event and daily cumulative levels. This noise dose design should provide sufficient data to establish a relationship between cumulative event levels and a single event level suitable for incorporation into a noise regulation. The final determination of the actual levels will be based on which off design conditions are able to be flown and will be determined by NASA. Operational flight constraints, and anticipated participant response considerations will be included when determining the optimal separation between the presentations of individual booms. The number of booms per day, the separation of booms between flight sequences, and the distribution of booms among the sequences is yet to be determined. We acknowledge that the boom order and the boom spacing could potentially change on a daily basis due to operational and environmental considerations. The planned time periods will be distributed throughout the day and over the test period. The test duration is likely to be a 3 to 4 week period that is yet to be determined

5.3 Noise Dose Distribution

The noise impact field test is the central piece of the LBFD test design and must be implemented to gather response data from participants assessing single events and summary of their daily noise impact. The test is designed to assess responses to individual sonic boom levels, daily boom levels, number of booms and the distribution of booms throughout the day. The noise dose is patterned after the WSPR 2011 dose design and based on the operational conditions predicated by NASA. The test will include one week of orientation or acclimation, which will be delineated in the data analysis as the acclimation period. The acclimation period will present a lower number and daily level of boom impact. The noise dose presented in the following two weeks of flights will be greater in terms of single event levels and cumulative numbers of events than during the acclimation week. Two patterns will distribute booms throughout the day over either a 9 hour period or a 12 hour period. The noise dose will be matched between days using the cumulative dose. See Table 5-1.

Table 5-1 Noise Dose Presentation Patterns

Conceptual Presentations Patterns
Orientation week:
First week presenting a lower number and lower daily level of boom impact
Clustered "Rush Hour" Presentation:
Flights in the early AM, mid-day, and late PM with 12 hours between first and last flights
Distributed "Leisure Travel" Presentation:
Flights distributed throughout the day over either a 9 hour or 12 hour period
Flight Tempo
Monthly Site Deployment:
Acclimation period in 1st week
2 weeks of testing
1 week for "replacement" days (in the event flight days are cancelled)
Testing conducted on weekdays and weekends
Daily test period from 7 AM to 9 PM
Boom Presentation Patterns:
2 -3 booms per flight
Booms spaced 30 minutes apart to allow participants time to respond
Three flight operations over a ~9-hour span OR
Possibly four flight operations over a ~12-hour span
Boom Levels
Design Incorporates 4 boom level targets, A-Lowest, B-Low C-Med, D-High
On-Design Sonic booms in range of PL ~ 70-75 dB across the carpet
Sonic boom levels up to a PL of 85 dB achievable at off-design conditions

Two conceptual presentations will be implemented using the two noise dose patterns. One concept will simulate a "business rush" focused presentation of booms, where the flights will be clustered in the early AM, mid-day and later in the PM to simulate cross country business travel. For business rush, there will be 12 hours between the first daily flight and the last daily flight. This pattern is being included to model the potential future cross country noise exposure pattern as a result of anticipated daily business flights between East and West coast hubs, such as New York City and Los Angeles. A second pattern will pattern "leisure travel" where the flight times will be spread out during the day. This pattern is randomized throughout the day, a distribution which is more typical for a noise exposure test. Embedded within the leisure travel distribution will be a sequence with flights early morning, mid-morning, mid-afternoon and early evening, to simulate the pattern typically observed at larger airports for current air travel. It is intended to capture a broader range of response variables such as a variety of climate and meteorological effects, differences in participant locations and activities, and variances in ambient outdoor levels.

The design is based on the elements presented in Table 5-1. Some of the specific flight parameters have not been fully defined, so the following is an example of the noise design process that will be implemented once all parameters are finalized. The sample design implemented either 3 flights per day, or 4 flights per day, with 2 to 3 booms per flight. A critical component is the potential to vary the noise dose by using either off design flight operational scenarios or by laterally offsetting the center line of the flight path. A lateral offset would provide additional noise dose variability under the "shifted" carpet path. A lateral shift of the center line will correspondingly shift the noise impact in one direction, exposing people outside of the test area on one side of the flight track while the opposite side of the flight path will experience quiet or diffuse noise associated with being just outside of cutoff. The intent is to vary the noise impact to respondents under the flight path, either through shifting the carpet path laterally or changing the noise impact by using off design flight parameters.

The noise distribution across the carpet region has been defined to range from approximately 70 dB PL up to a potential 85 dB PL. To vary the noise dose, it would be ideal if off design operational scenarios could afford that range of boom impact over the center line under the flight track, with the levels at the lateral edges tracking accordingly. This variability in noise dose on different days would allow for the comparison of similar noise impact between respondents located at center line and lateral edge communities when comparing across daily dose response. Since the range at center line is not yet determined, the final noise dose plan will be developed in Phase 2.

The noise dose exposure determination process is patterned after the WSPR noise dose process. The range of potential noise impact from 70 dB PL to 85 dB PL across the carpet was used to represent the range of potential impact under the flight track at center line using off design flight scenarios. Metrics for the four levels were computed in PCBoom Burgers Solver using U.S. standard atmosphere with an ANSI % Relative Humidity Profile. The associated levels are presented in Table 5-2.

Table 5-2 Low Boom Flight Metrics

NASA Low Boom Flight Demonstrator Metrics						
Metrics computed using US Std. Atmo., with ANSI %RH Profile						
PCBoom - Burgers Solver					Flight Conditions	
Level	PL	CSEL	ASEL	MaxPsf	Mach	Alt
A	70.0	84.7	56.4	0.19	1.5	54.0
B	75.0	89.2	61.0	0.31	1.6	54.0
C	79.9	92.9	65.8	0.48	1.6	41.5
D	85.0	96.1	71.0	0.68	1.6	32.7

The metric values computed using PCBoom were compiled within a table to calculate the cumulative metric value for various combinations of input level. Table 5-3 presents a sample calculation for a daily noise dose comprised of 7 low booms, consisting of 2 Level A (lowest), 2 Level B (low), 2 level C (medium) and 1 level D (high). The Cumulative Metric Value is tabulated for DNL (PL), CDNL and DNL.

Table 5-3 Sample Cumulative Metric Values

NASA LBFD Undertrack Metric Values *Note: Cumulative Metric Value: No Evening / Night Time Penalty						
Levels	PL	CSEL	ASEL	MaxPsf	**Enter Number of Events**	**Level of Event**
Level A Lowest	70.0	84.7	56.38	0.19	2	A Lowest
Level B Low	75.0	89.2	60.98	0.31	2	B Low
Level C Med	79.9	92.9	65.83	0.48	2	C Med
Level D High	85.0	96.1	71	0.68	1	D High
Cumulative Metric Value	**35.0**	**46.6**	**21.0**			
	DNL(PL)	**CDNL**	DNL			

The number of events input variable can be changed to create various combinations of boom input, to determine the cumulative metric value that represents the daily noise dose. This range of noise dose levels was used to calculate daily metric values for multiple combinations of boom impact (Table 5-4).

Table 5-4 Sample Excerpt of Boom combinations and Cumulative levels

Boom Combinations and Cumulative Levels							
Level A Lowest	1	1	2	2	2	3	3
Level B Low	1	1	2	2	2	2	3
Level C Med		1	1	2	2	2	3
Level D High			1	1	2	2	3
Total Booms	2	3	6	7	8	9	12
DNL(PL)	26.8	32.0	37.6	38.4	40.2	40.3	42.0
CDNL	**41.1**	**45.5**	**49.8**	**50.7**	**52.1**	**52.2**	**53.9**
DNL	12.9	18.0	23.6	24.3	26.2	26.2	28.0

The process was repeated for approximately 100 iterations of boom combinations that summed booms across varying levels, with a different number of booms at each level, up to an input of 12 booms total per calculation. This provided a potential range of CDNL metric values that was then compared to both WSPR and CHABA CDNL values (see Table 5-5).

Table 5-5 CDNL range for Boom and Blast field tests

Source	Team	Approx. CDNL**
Shaped Boom	WSPRRR Planning	39.8 -57.5
Low Boom	WSPR NASA, 2011 EAFB	47.4 – 56.9
Sonic Boom	Borsky, 1965, Oklahoma City	54 – 64
Sonic Boom	Fields et al., 1994 Nellis AFB	38 - 56
Artillery	Schomer 1981, Ft. Bragg	58 – 70
Gunfire	Rylander Lundquist, 1996 Sweden	41 – 68
Artillery	Schomer, 1985, Fort Lewis	51 – 65

Based on the CDNL comparison a range was determined that fit with the output from the boom combinations and cumulative levels tabulations and encompassed the prior test CDNL ranges. A color coded range of CDNL values (Table 5-6) was identified and various boom combinations were then sorted into those ranges.

Table 5-6 Color coded range of potential CDNL values

Color Code	Perception	CDNL
	Quietest	40 - 43.9
	Quiet	44 - 47.9
	Moderate	48 - 50.9
	Mod. Loud	51 - 53.9
	Loud	54 - 57.5

The boom combinations were grouped by range and then paired for similar CDNL level to afford matched test days within the daily design. The decision was made to use CDNL rather than DNL to match test days, since CDNL is the metric most commonly used to represent community noise impact from impulsive sources such as blast or boom noise. Combinations that yielded closely match CDNL cumulative levels were selected for inclusion in the daily noise dose design.

Table 5-7 Matched range of CDNL values for cumulative daily noise dose

Potential Range of WSPRRR Daily Cumulative Noise Exposure Dose								
Levels	4A	1A, 1B	1C	1A,2B	3B	8A	1A, 1B 2C	6B
DNL(PL)	26.7	26.8	30.5	29.2	30.3	29.7	34.4	33.3
CDNL	**41.4**	**41.1**	**43.5**	**43.5**	**44.6**	**44.4**	**47.6**	**47.6**
DNL	13.0	12.9	16.4	15.3	16.4	16.0	20.3	19.4
Levels	2A,2B,2C	1A, 7B	12B	2A,2B,2C,1 D	2A,2B,2C,2 D	3A,2B,2C,2 D	2A,2B,3 D	3A,3B,2C,2 D
DNL(PL)	35.1	34.2	36.3	38.4	40.2	40.3	40.8	40.4
CDNL	**48.5**	**48.5**	**50.6**	**50.7**	**52.1**	**52.2**	**52.2**	**52.5**
DNL	21.0	20.2	22.4	24.3	26.2	26.2	26.8	26.4
Levels	2A,2B,1C ,4D	3A,3B,3C,3 D	3A,3B,1C,4 D	1A,2B,4C,5 D	2A,2B,2C,6 D	1B,1C,7D	1B, 3C, 8D	4C, 8D
DNL(PL)	42.2	42.0	42.3	43.7	44.0	44.3	45.2	45.3
CDNL	**53.7**	**53.9**	**53.9**	**55.4**	**55.4**	**55.5**	**56.5**	**56.7**
DNL	28.2	28.0	28.3	29.7	30.0	30.3	31.2	31.3

To attain the higher levels, it is often necessary to use more than 9 booms. The desired separation time between booms is 30 minutes to afford respondents the opportunity to break from their daily activities and submit a response. With 2 to 3 booms per flight, the design would require 4 flights to provide the 12 boom necessary to produce higher range CDNL levels. The final range will be determined in Phase 2.

The matched cumulative noise doses were than distributed across a sample test presentation plan. Each day in the test is matched in noise dose to another test day. The plan provides the test day, the time of the flight, the number of booms per flight, the level of the booms for each flight, the daily boom exposure, the number of flights per day, the cumulative daily noise dose and the test day in the design that matches that daily dose. . This matching of doses affords the ability to compare the response rankings between the same individual on different days, as well as comparing across respondents on any day. The plan is to provide 4 days of acclimation in the first week of the test that present low levels of boom to gradually introduce the community to the boom noise. The test includes both weekdays and weekends. The moderate level booms are introduced on the first test weekend. A sample plan is presented in Table 5-8. The actual noise dose plan will be finalized once the characteristics of the low boom flight demonstrator are more fully defined, providing critical elements to the noise dose design. The analyses presented in Section 9 will identify a relationship between the annoyance observed and the metric values measured as an outcome of the implementation of the field noise plan.

Table 5-8 Excerpt WSPRRR Matched Daily Cumulative Noise Dose Plan

Partial sample of WSPRRR Matched Daily Cumulative Noise Dose									
Acclimation 4 Days	Test day	AM (Time) Booms/Flight	Level	PM Booms /Flight	Level	Booms /Day	Daily Exposure	Flights/Day	Test Day Match CDNL
Mon	1	(10-11)		(1-2)				2	1--4
		1//1	1A	2//1	1B	2	1A,1B	CDNL	41.1
Tues	2	(7-8)		(2-3)				2	2--3
		2//1	2B	6//1	1A	3	1A,2B	CDNL	43.5
Wed	3			(12-1)				1	3--2
		----		1//1	1C	1	1C	CDNL	43.5
Thurs	4	(8-9)		(5- 6)				2	4--1
		2//1	2A	2//1	2A	4	4A	CDNL	41.4
Start Test Week 1	Test day	AM (Time) Booms/Flight	Level	PM Booms /Flight	Level	Booms /Day	Daily Exposure	Flights/Day	Test Day Match CDNL
Fri	5	(7-8)		(12-1)				3	5--8
Rush		2//1	1A,1C	3//1	1B,1C,1D				
				(6-7)					
				2//1	1A,1B	7	2A,2B,2C,1D	CDNL	50.7
Sat	6	(10-11)		(3-4)				3	6--9
		2//1	1A,1D	3//1	1A,1B,1D				
				(7-8)					
		5//1		2//1	1B,1D	7	2A,2B,3D	CDNL	52.2
Sun	7	(9-10)	1B	(12-1)	1B			3	7--10
		1//1		1//1					
				(8-9)					
				1//1	1B	3	3B	CDNL	44.6
Test Week 2	Test day	AM (Time) Booms/Flight	Level	PM Booms /Flight	Level	Booms /Day	Daily Exposure	Flights/Day	Test Day Match CDNL
Mon	8	(7-8)		(2-3)				4	8--5
		3//1	3B	3//1	3B				
		(10-12)		(6-7)					
		3//1	3B	3//1	3B	12		CDNL	50.6
Tues	9	(9-10)		(12-1)				2	9--6
Leisure		3//1	1A,2B	**2//1**	1C,1D				
				(3-4)					
				2//1	2A				
				(7-8)		9		CDNL	52
				2//1	1C,1D				
Finalized in Phase II									

5.4 Acclimation

An individual's personality, mood, environment, and current activity can all contribute to their unique perception of the noise impact. The ability to acclimate to noise is related to components of an individual's response to the noise. Whether or not the noise provokes annoyance, or a strong emotional response, influences the ability to acclimate to that noise. The WSPR baseline survey will be reviewed and a majority of the questions will be included in the WSPRRR baseline survey. Some of the questions were designed to assess the respondents' perception of an individual's ability to adapt to noise, the extent to which they feel that they are sensitive to noise in their surroundings, and their perceptions of noise in general. The WSPR test was conducted in an acclimated community, and the participants were accustomed to hearing sonic boom noise. The WSPR findings indicated a perceived ability on the part of respondents to adapt to noise in their environment. When asked about their ability to adapt to noise, 95% of the WSPR respondents indicated that they felt that people, in general, and themselves in particular, can adapt to noise given time. Sixty percent of the respondents indicated that they could adapt to even the loudest noise, although a sizeable proportion (25%) actually responded that they moderately disagreed about adapting to even the loudest noise. This observation in WSPR is consistent with prior findings that approximately 20% of the population is considered to be noise sensitive. A 1999 review of field surveys on transportation noise found that the incidence of noise sensitivity among a sample of 15,171 people was 22% [Luz, 2005]. The variables in Table 4-1 that are addressed within the surveys were designed to assess and evaluate each respondent's pre-conceived perspective on their ability to acclimate to noise, as well as to assess their noise response across the test duration.

The anticipated noise dose varies as a function of location under the flight path. The noise impact directly under the track is anticipated at approximately 75 PLdB, with off-track levels anticipated at approximately 70-75 PLdB. In off design conditions it may be possible to present a level as high as 85 PLdB. It is likely that the low boom level will not elicit a large number of responses in the defined range for % Highly Annoyed. As such, we do not anticipated that the low booms will have a highly notable impact on the test community. However, the first few days of the noise dose will have lower cumulative daily doses, either due to level, or number of booms, to afford an introduction of the noise to the community. Previous research has shown that the net effect of habituation and sensitization is dependent on the interaction between stimulus level and number of stimuli [Petrinovich, 1984]. That is, the level and number of booms per day may affect the ability of a community to acclimate to the noise. This is in keeping with anecdotal recommendations that a new noise source should be introduced gradually to communities in order to afford the community the opportunity to adjust and acclimate to the noise. As such, we will plan a short introductory period with the highest number of booms presented as the noise dose on a day that occurs later in the field test.

6. Objective Measurements

The statement of work for this task calls for an assessment of methods for quantifying the sonic boom exposure of study participants; with consideration to both measurement-based and prediction based methods for estimation of single-event and multiple-event sonic boom exposure. The primary purpose of these measurements is to develop methods to determine noise-annoyance dose-response relationships for single- and multiple-events. Test day atmospheric conditions will be recorded and archived to support prediction based methods for estimation of sonic boom exposure. Details of our approach to satisfy this objective are presented in section 6.4.1. Secondary objectives include the following:

- Record sufficient data to assess sonic boom levels to correlate with potential complaints or damage concerns
- Understand non-low-boom sources that potentially cause participant response (misattribution to a sonic boom),
- Measure the full carpet of exposure including areas outside anticipated participant locations to document sonic boom levels,
- Evaluate land-based focus and climb sonic boom levels and extent,
- Conduct focus monitoring (placement avoidance success),
- Provide ambient data for monitoring locations for use in determining noise-dose.

In addition to the instrumentation described below it will be an important function that all personnel involved in the actual testing (LBDM & LBFD) to make a note of what they hear & observe; for example: did they hear 1 or 2 booms, what did they sound like, were you startled, was it calm or windy, etc. - maybe all have a check off list. A check list/log will be maintained by all personnel throughout the LBFD Test Deployment. This type info has been very useful in the past for determining where and when the booms were experienced in addition to resolving many questions relative to the nature of the measured signature (a sharp boom- boom signifies a peaked signature and a soft or muffled boom -boom would suggest a rounded signature). These would be secondary observations/measurements utilized to clarify those collected through instrumentation.

6.1 Acoustic Instrumentation

The LBFD Test Deployment will encompass a very large area, making the collection of accurate objective noise data with high certainty very difficult. Historically, sonic boom flight testing has demonstrated that loudness levels of traditional booms can vary on order 5-10 PLdB over distances of less than a half mile. Although low booms haven't been fully characterized with flight testing, it is anticipated that signatures may still vary by more than 3 PLdB over short distances, increasing the probability of high uncertainty in the objective data measurement.

Our team proposes a mixed-fidelity solution for collecting acoustic data to mitigate the cost burden of utilizing high-fidelity systems in very dense arrangement across the test site. The approach includes the WSPR 2011 sonic boom field kits, some new low cost noise monitors, and possibly some low fidelity sensors being studied in the FAA's ASCENT program. The following sections detail these monitors and their planned deployment for effective measurement of the low boom.

For the LBFD testing we recommend calculation of outdoor sonic boom metrics (Table 6-1) as were computed in the WSPR 2011 testing [Page *et al.,* 2014]. The accuracy of noise monitoring systems across a range of metrics should be assessed to guide decision makers on future policy development. More recent discussions within the scientific and regulatory working groups hint that a hybrid metric may eventually emerge combining two or three traditional metrics, such as PLdB, dBA, dBC etc. Our mixed fidelity concept may provide additional insight into this process with a large dataset of correlated objective and subjective community data.

Table 6-1 Outdoor Sonic Boom Single Event Metrics Recommended for the LBFD Regional Testing

METRIC LABEL	DESCRIPTION
PL	This is an estimate of Stevens Mark VII Perceived Level [Stevens, 1972] calculated using a time constant of 70 msec and averaging across the two peaks, which means 3 dB is subtracted from the 1/3 octave band levels calculated from the spectrum for the entire boom before the PL metric is calculated [Shepherd and Sullivan, 1991].
CSEL ASEL ZSEL	C-, A- and Z- Weighted Sound Exposure Level (SEL) values (time constant is 1 sec; there is no averaging).
LLZf LLZd	Zwicker loudness levels in phons, for frontal incidence and diffuse incidence, calculated using a time constant of 70 msec and averaging across the two peaks.
PNL	Kryter's [1959] Perceived Noise Level, calculated using a time constant of 70 msec and averaging across the two peaks.
maxpsf	Outdoors peak overpressure in psf.
iSone iPhon	Maximum instantaneous value of the Moore & Glasberg Time-Varying Loudness in units of Sones and Phons.
Av1Sone Av1 Phon	Maximum of the short term average value of the Moore & Glasberg Time-Varying Loudness in units of Sones and Phons.
Av2Sone Av2 Phon	Maximum of the long term average value of the Moore & Glasberg Time-Varying Loudness in units of Sones and Phons.

6.1.1 WSPR Sonic Boom Unattended Data Acquisition System

The Sonic Boom Unattended Data Acquisition System (SBUDAS), also known was Sonic Boom Field Kits, were the primary sonic boom recording systems for the WSPR experiment. The field kits consist of National Instruments (NI) acoustic measurement and acquisition hardware and are controlled via NI LabVIEW software. Each field kit is comprised of a NI compactRIO (cRIO) hardware featuring a 9023 controller chassis, a 9234 Dynamic Signal Acquisition (DSA) module, 9870 RS232 module and 9401 digital I/O module. Other field kit components include a GPS antenna, two GRAS 40AN microphones with GRAS 26AJ LEMO preamplifiers, and a two-channel GRAS 12AQ signal conditioner/power module. The system is powered by a 105 Ah 12V deep cycle battery that is charged by a 120W solar panel. Systems can be built into environmental enclosures for protection, leaving microphones to be deployed on the ground inside GRAS 41AO systems providing waterproof windscreens and desiccant.

The combination of the NI hardware and the GRAS low-frequency microphones and preamplifiers make the SBUDAS high-fidelity noise monitoring equipment. Measurements can be made with 24-bit resolution at sample rates up to 51.2 kS/s, simultaneously sampled across the channels. Systems are time-synchronized by the GPS receivers.

The approximate cost of a single SBUDAS field kit is $12,000.

6.1.2 Low Cost Acoustic Instrumentation

A given LBFD Test Deployment will have a sonic boom carpet region that covers approximately 2000 square miles. In this carpet region there will be multiple communities selected communities with approximately 1000 participants distributed across them, requiring a significant number of noise monitors to ensure accurate determination of noise dose at or near a respondent's location. The SBUDAS high fidelity noise monitoring equipment utilized during WSPR 2011 cost approximately $12,000/unit; our assessment as described in section 6.4 calls for between 65 and 80 units for a LBFD Test Deployment we have initiated investigations into Low Cost Noise Monitors.

Commercial Off The Shelf (COTS) components have been identified that can be integrated to support Low cost monitoring systems able to obtain metrics within 0.1 – 1.0 PLdB. Such a system would consist of:

- Cellular phone – providing network capability and GPS for location and time synchronization
- Battery – with solar recharge capability for extended unattended operations
- Signal Conditioner
- Preamplifier
- Microphone

The signal conditioner and preamplifier could be integrated into a small electronic circuit board supporting 24 bit resolution for best dynamic range and a 48 kHz sampling rate. This could be integrated into a weather proof package for easy deployment as shown in Figure 6-1. If the microphone must be located at ground level, when placed on soft earth, this package could be easily set below ground level with the microphone exposed on the surface. It is anticipated that grazing angle at the extents of lateral spread of the low boom will be a more significant factor than ground impedance.

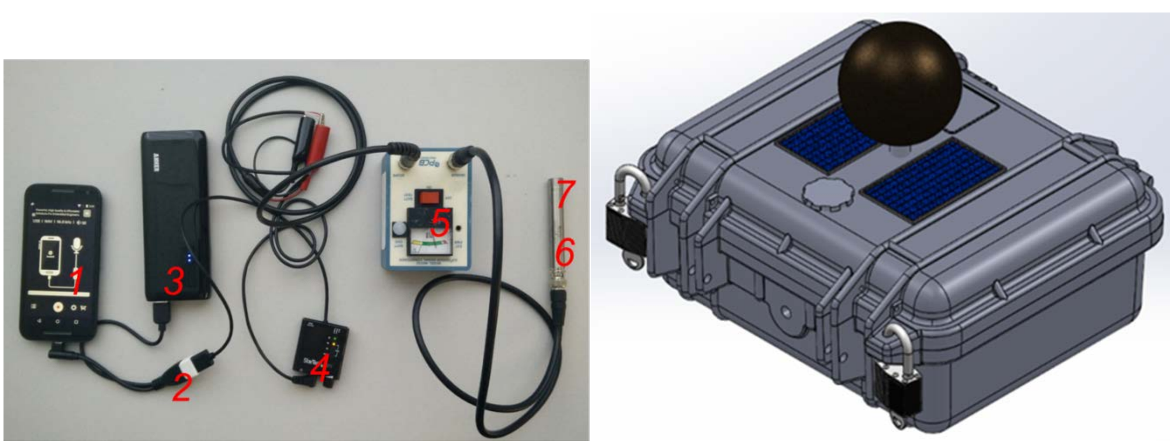


Figure 6-1 Low Cost Acoustic Instrumentation Concept

For known flight times, the simplest option is to just record everything. From that we could determine causes of misattributed responses to non-booms. For non-flight times we would utilize these noise monitors on a periodic basis to determine local ambient noise levels.

6.1.3 Noise Monitoring Network

Quantification of the sonic boom exposure to study participants will require a wide distribution of noise monitors across the low boom carpet region as discussed in Section 6.4. Efficient operation of these noise monitors and the retrieval of data from them will require near real time network access with each from a central location. Such access will support the QueSST Test Deployment by providing feedback on at least a daily basis that: the boom footprint was correctly placed and measurement of the low boom reaching the study communities and ultimately the correlation of the noise dose with participant surveys.

An advantage of the WSPR experiment at EAFB was that the subjective respondents were densely located over an area of approximately 1 mi^2. This allowed for the 13 SBUDAS to be networked to a host station by using of bi-directional, long range 2.4GHz wireless G Wi-Fi through the field kit TCP/IP network connections on the cRIO 9023 chassis. Limitations of this sort of network is that it is generally restricted to line of site operations for effective, continuous operation and wireless repeaters are required for long range operation, increasing the number of potential failure points between a field kit and a host station. Equipment tests prior to the WSPR experiment showed that individual repeater units needed to be configured with multiple routers and antenna in an Access Point/Client configuration to improve network reliability and performance. Additionally, it was determined that the communication chain should not perform more than three "hops" to ensure network integrity. A total of five repeaters were used in the densely spaced community at EAFB (Figure 6-2).

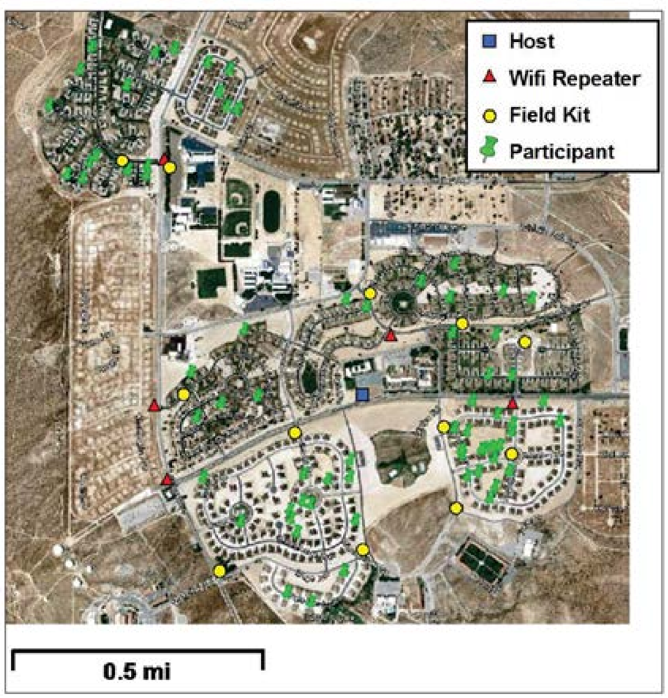


Figure 6-2 Community Layout for 2011 WSPR Test

Due to the anticipated expansion of the community footprint for the LBFD experiment (as described in section 6.4), along with the understanding that respondents may be clustered within different areas inside of these larger communities, it is not likely that the networking strategy employed in WSPR will be sustainable. Thanks to the expansion and improvements of cellular networks over the past half of a decade, the best option for networking remote noise monitors lies with cellular connectivity.

Since the SBUDAS nodes already feature TCP/IP network connectivity and are programmed with set static IP addresses, the modification effort would be consist of obtaining and configuring cellular modems for individual nodes, and establishing a base station and VPN server for network connectivity (Figure 6-3).

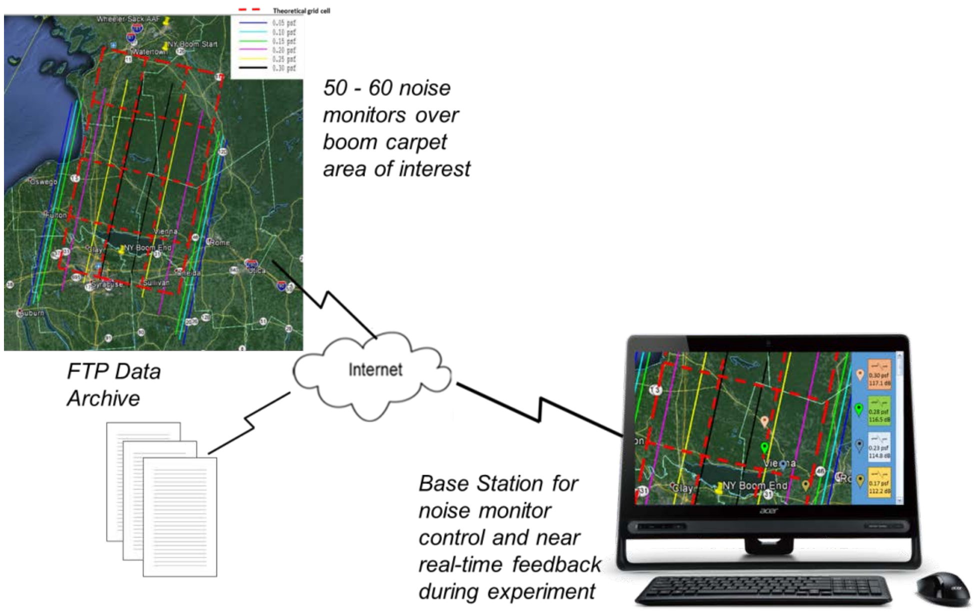


Figure 6-3 SBUDAS Network Connectivity

This method of networking the individual noise monitors is intended to allow the download of data recorded at all noise monitors within an hour of the last pass of the aircraft of the day. Processing of this data to provide noise metrics for review by the test director is anticipated to be feasible within two hours of data download. A full analysis of all of the measurements correlated with the subjective responses (as described in Section 9.3) will not be accomplished until all measurements are finished and a full listing from all flights at participant locations is finalized.

6.1.4 Cellular Modems

Cellular modems or routers, such as the Digi Connect product line, can be purchased with the capability of supporting 10/100/1000 Ethernet connections and operating at 2G (Edge), 3G, or 4G (LTE) speeds on CDMA (Verizion/Sprint) or GSM (AT&T/T-Mobile) networks. Modems offer basic routing and security, with enterprise versions providing advanced routing and security/VPN. These systems are designed to run in remote, low power applications and can be powered using the system 12V batteries.

A modem such as the Digi TransPort WR11 in its North American 4G LTE GSM configuration would be capable of support 4G data on 700/850/1700/1900 MHz bands with 2G and 3G fallback on 850/1900 MHz (AT&T provider) bands with maximum transfer rates on supporting networks of 50 Mbps upload and 100 Mbps download. These modems cost about $370 each (as of mid-2015) and feature plastic cases since they are designed for permanent installations for equipment such as ATMs or Kiosks.

An alternative option is the Digi WR21-L52B series modems – these have cellular chipsets that allow for them to be used with any carrier using a SIM card at 4G/LTE speeds since 4G uses GSM bands and are therefore available from CDMA providers. These units provide 2 Ethernet connections and a rugged construction with a metal case. These modems cost about $530 each (as of mid-2015) without SIM cards or data plans.

All noise monitors would be connected to cell modems and could be assigned a static IP based on the unit MAC Address.

Base Station – VPN Server and Web Host

A base station computer running NI Labview is required to configure and set triggers for the remote noise monitors. Any computer running Windows 7 or Windows 8 has the ability to natively operate as a VPN server without any sophisticated or expensive software. If a computer were configured and connected to act as a server, it could also operate as a remote webhost for noise monitor triggering, monitoring, and data retrieval. Data collected by remote noise monitors would be able to be securely transmitted over the cellular VPN to a base station via any File Transfer Protocol (FTP) software for remote data collection purposes. Remotely retrieved data would continue to be stored locally on the noise monitors for redundancy.

The base station system could be tied into the network by using a cellular modem, like those used for the SBUDAS, however the amount of bandwidth it would consume would scale by the number of SBUDAS receiving triggers and health queries, and responding with data files. It would be preferable that a Base Station be setup on a network capable of supporting continuous, high bandwidth use.

Data Plans

Thanks to the expanding consumer cellular market, a variety of mobile broadband data plans are available for supporting tablets and SIM card enabled PCs. These can be purchased under different terms of use, bandwidth, and for different durations depending on operational needs.

- If long term data connectivity is required, contract based machine to machine (M2M) data plans from major carriers such as Verizon or AT&T may be preferable for stability. In 2014, 3G data plans with 5GB bandwidth caps were available for a contract rate at $60/month.
- Reviewing mobile broadband data plan for tablets (mid-2015), medium term monthly contracts, or prepaid plans with 30-day expiry periods, can be purchased for less than $10/GB of data at 4G speeds – with prices falling for higher bandwidth requirements.
- Short term (1 to 7 day) prepaid plans can be purchased at costs between $10-20/GB at 4G speeds.

Many of these plans require an upfront cost of $10-15 for carrier SIM cards. Day to week long plans are unlikely cost-effective options when considering the man-hours that will be required to activate all the network nodes and configure the modems.

6.2 Meteorological Instrumentation

The influence of the atmosphere on propagation of sonic booms can be defined in terms of the macro and micro effects; macro being associated with the effects of pressure, temperature and wind profiles and micro effects being associated with turbulence, especially in the first few thousand feet of the earth's atmosphere [Maglieri *et al.,* 2014].

Macro effects will result in refraction of sonic boom energy as they propagate to the ground resulting in variations in sonic boom strength and/or its footprint. The upper atmosphere must be monitored so that its affect can be analyzed through the use of PCBoom; for example: The assessment of the planned flight trajectory to ensure delivery of the proper noise dose across the subjective communities on the day of flight. These measurements will additionally be utilized to support post flight analysis to more precisely (spatially and temporally) determine the noise to which participants responded.

The turbulent process in the atmosphere (micro effects) is the result of some form of instability that produce random fluctuations; these translate to signature distortions at different points across the boom carpet. In most cases there is a diurnal effect observed where in the morning a quiescent period occurs, followed by increasing turbulence corresponding with solar heating through the course of the day. Atmospheric turbulence are difficult to directly measure though their presence can be indicated through surface measurements of the atmosphere and acoustic measurements of the variability of the boom signature. Monitoring these atmospheric conditions during the flight will support post flight analysis in accounting for any spikes or rounding of the boom signature in the measurements.

6.2.1 Meteorological Data Acquisition

During WSPR 2011 the F-18 waypoints required in the execution of a low boom dive maneuver were calculated on recent GPS rawinsonde upper air meteorological data as well as an assessment of the best flight cards to be flown depending on the atmospheric conditions over the single community surveyed. Additionally two ground based surface weather instrumentation systems were utilized to collect atmospheric pressure, temperature, relative humidity, wind speed and direction at a 1 Hz rate [Page et al., 2014]. The primary differences between the approach utilized during WSPR 2011 and what is required for the LBFD experiment are:

1. WSPR 2011 was conducted over a single community (approximately 3 square miles) whereas the LBFD experiment will include a carpet boom region of approximately 50 miles in length and 35 miles in width (1750 square miles).
2. F-18 waypoints in the execution of a low boom dive maneuver will not be required. The LBFD will fly at a constant altitude over the carpet boom region. It is anticipated that one or more GPS rawinsondes will be required to refine the trajectory flown across this region.

The size of the low boom carpet region mandates maximizing the use of existing meteorological infrastructure for the collection of data across such a region as well as complimenting it with low cost sensors deployed in the communities being surveyed as well as the use of high resolution numerical weather modelling to support post flight analysis (see 9.1.4).

The existing meteorological infrastructure includes National Weather Service data feeds (Text, RSS and XML) providing observed current weather conditions for about 18,000 locations across the United States. Aviation Weather Products available for download and archive include:

- METARS – surface weather observations issued hourly
- Aircraft Reports – Aviation weather provided from transiting aircraft
- TAFS – Terminal Aerodrome Forecasts issued every six hours from major civil airfields
- AIR/SIGMETS – Significant weather conditions distributed by the National Weather Service as they develop

A review of our Florida example under consideration indicates that 17 sites could support archival of surface weather observations (Figure 6-4).

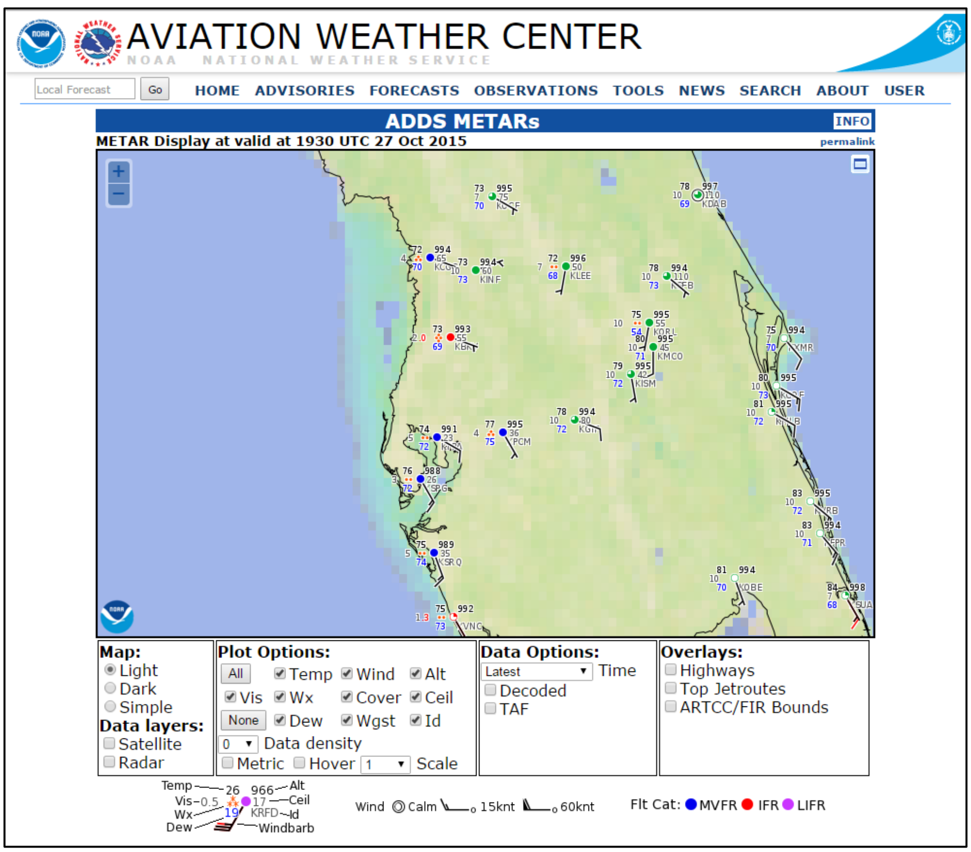


Figure 6-4 NOAA METAR Observation Sites Available for Data Archive Between Orlando and Tampa

The limitations of NWS resources are that they provide periodic updates from fixed locations which may not be suitable for all of the sites currently under consideration. It is advised that a small number of self-contained commercial weather stations be installed in the center of each community across the survey area. The advantage of deploying these systems is that their continuous measurements can be most accurately correlated with the time of the boom at a given location. Additionally these systems distributed across the communities in the carpet region would provide an indication of near surface turbulent conditions for correlation with noise measurements in their vicinity. These monitors would additionally provide specific observations that could be used as inputs to high resolution numerical weather predictions; and finally they would provide an absolute source of surface atmospheric conditions over which the analysis team has direct control. Weather stations such as the Davis Instruments 6250 (Figure 6-5) support an IP interface allowing these to be integrated into the Noise Monitoring Network for real time monitoring as well as archival of atmospheric data at each site for post experiment analysis.

Figure 6-5 Davis Weather Station (6250)

Upper air soundings are far less available through the existing meteorological infrastructure. The National Weather service collects upper air soundings twice a day (up to an hour before 00:00 and or 12:00 UTC) at 69 locations in the continental United States (Figure 6-6).   These are intended to support regional weather forecasts. Specific observations associated with these sites are available in a number of formats going back to 1946 [NOAA/ESRL Radiosonde Database]. These are not likely sufficient to support "Day of Flight" planning, however they could be useful in characterizing the elevated atmospheric conditions associated with candidate sites.

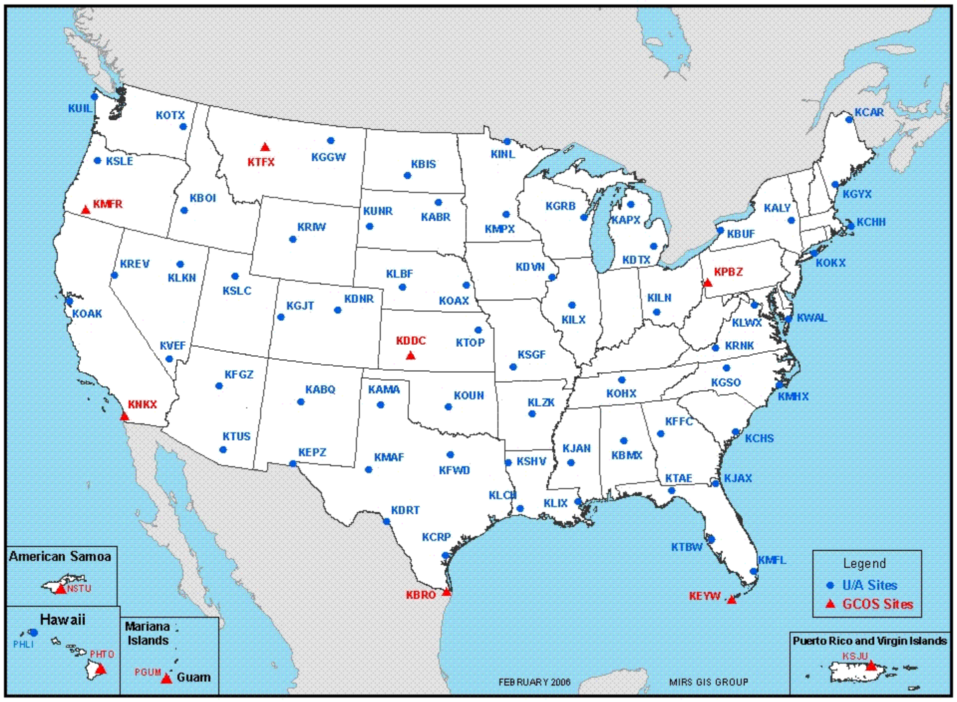


Figure 6-6 Upper-Air Network; GCOS – Global Climate Observing System

(http://www.ua.nws.noaa.gov/nws_upper.htm)

6.2.2 Meteorological Data for Day-of-Flight Planning

On the day of flight NASA resources will be relied upon for the collection of upper air data. Atmospheric soundings should be made simultaneously along the length of the trajectory. These measurements shall be made in accordance with NASA protocol and procedures. It is anticipated that measurements will be made prior to the first flight and thereafter as dictated by changing weather conditions. The distance interval between soundings will depend upon the site. Were the study area to traverse a mountainous area as would be found in Colorado or some other location with distinct weather patterns created by a geographic feature, then rawinsondes would need to be launched in each of these areas. In the case presented in Figure 6-13 where the study area spans the width of Florida, soundings would be made simultaneously at the beginning, mid-point, and end of the trajectory. If the focus zone and/or the climb region are on land, additional measurements should be made in each of those regions as well; otherwise a measurement should be made at the land/sea interface. It should be noted that atmospheric soundings accomplished through the use of "weather balloons" are neither instantaneous nor true vertical measurements. The NOAA National Weather Service Fact Sheet for Radiosonde Observations notes "A typical NWS "weather balloon" sounding can last in excess of two hours. In that time, the radiosonde can ascend to an altitude exceeding 35 km (about 115,000 feet) and drift more than 300 km (about 180 miles) from the release point [NOAA National Weather Service Radiosonde Observations]." Whether the different soundings alter the footprint and by how much will determine their usage in predicting the noise exposure at participant households.

Surface atmospherics will be monitored and archived throughout the day to stay abreast of turbulence conditions and to support post flight analysis.

Local resources shall be monitored as available and recorded in a running log. For example, if the study area includes a major metropolitan area, it is likely that a TV station has a meteorology department with a Doppler radar. While not essential to the test plan, such data could be used to ascertain the amount of turbulence in the atmosphere.

6.3 Aircraft Instrumentation Needs

The LBFD aircraft onboard instrumentation requirements to support the dose-response testing should include at a minimum:

- GPS time synchronized positional information
- Mach meter with sufficient precision/response from which Mach rate and second derivatives can be determined
- Aircraft orientation (roll, pitch, yaw) with sufficient precision/response from which first and second derivatives can be determined
- Propulsion system operating state information from which low-boom source characteristics can be determined (especially during climb and acceleration and turning maneuvers which could result in focused booms)
- Aircraft trim information – either primary or derived, from which low-boom source characteristics can be determined

6.4 Instrumentation Layout

The LBFD Test Deployment will encompass a very large area, making the collection of accurate objective noise data with high certainty very difficult. Historically, sonic boom flight testing has demonstrated that loudness levels of traditional booms can vary on order 5-10 PLdB over distances of less than a half mile. Although low booms haven't been fully characterized with flight testing, it is anticipated that signatures may still vary by more than 3 PLdB over short distances, increasing the probability of high uncertainty in the objective data measurement. The levels from the demonstrator are expected to be low, therefore it is possible that extracting the boom signal from background noise will be difficult. To that end, placement of the monitors should be done well away from known noise sources (roads, air conditioners, etc.).

Our team proposes a mixed-fidelity solution for collecting acoustic data to mitigate the cost burden of utilizing high-fidelity systems in very dense arrangement across the test site. The approach includes the WSPR 2011 sonic boom field kits, some new low cost noise monitors, and possibly some low fidelity sensors being studied in the FAA's ASCENT program. The following sections detail these monitors and their planned deployment for effective measurement of the community response across the low boom carpet.

Our approach for the deployment of noise monitors places a priority on ensuring that we have sufficient noise monitors in the communities from which we expect to receive responses. We will be flexible and support the placement of additional monitors in high interest areas or those areas shown to be prone to complaints. Secondary priorities include:

1. Validation that the focus/climb zones did not encroach upon the carpet region (where subjective respondents will be located).
2. Validation of the prescribed low boom noise dose under the flight track and across the width of the carpet region
3. Detection of atmospheric turbulence

Placement of monitors is driven by the community selection (geometrically) and PCBoom predictions of the low boom footprint, these will vary for each of the six regional sites. Suitable locations will need to be assessed for each monitor with requirements for accessibility, security, background noise etc. It is anticipated that the majority of monitors will not require to be relocated over the course of a LBFD Test Deployment. A smaller set of noise monitors will additionally be deployed in response to changing conditions including diurnal atmospheric changes, repeated respondent locations, and complaints.

Modeling the flight, with tools such as PCBoom, provides a near continuous estimate of the footprint throughout the study area to support definition of the proper trajectory to deliver the prescribed low boom over the region where respondents will be located. This modelling additionally will be utilized for planning placement of noise monitors for the purpose of obtaining source measurements for the determination of the noise dose for correlation with subjective responses. Possible differences between modelled and measured data may include variation in the aircraft data (e.g., tracking, attitude, etc.) and weather (i.e., the modeled atmosphere versus what exists at the time of flight). Instrumentation will provide the best measure of the sonic boom at the location it is deployed.

We estimate that between 65 and 80 noise monitors of sufficient fidelity to obtain accurate metrics are required to conduct the LBFD test. A notional distribution of monitors is presented in Figure 6-7.

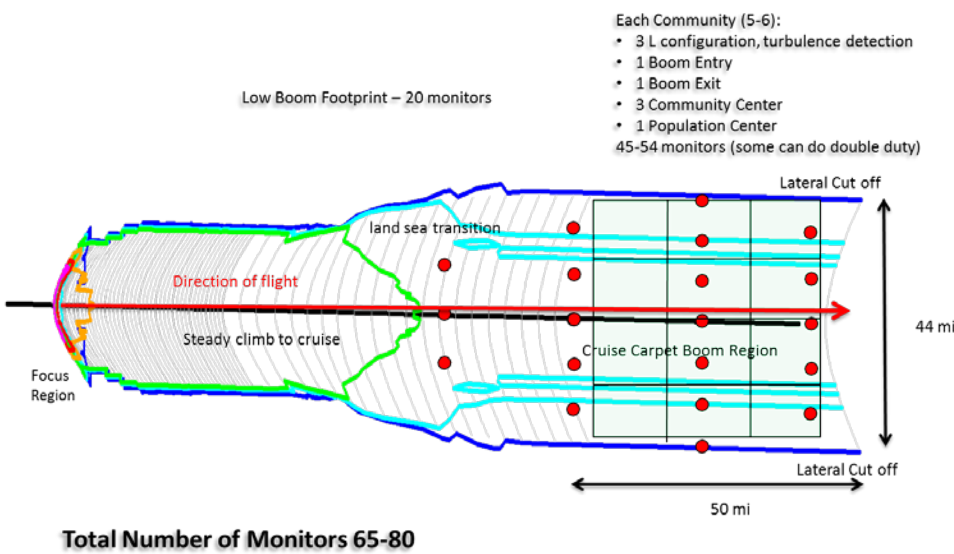


Figure 6-7 Notional Monitor Distribution for the Florida Site Example

Generated for the purposes of determining the quantity required

6.4.1 Instrumentation for Correlation with Subjective Response

Associating noise doses with subjective respondents at varying locations creates a significant challenge. Placement of a monitor at a respondent's location is not an estimate at all; it is an actual measurement of the sonic boom and all needed metrics can be calculated from the recording, without further influence from outside modeling or monitors. It is not possible, however, to monitor noise occurring around each subjective respondent.

Monitors placed near or around special points of interest enable the best estimate of the sonic boom at those locations. Our plan for the notional layout of noise monitors is based on studies conducted by Gulfstream Aerospace [Collmar *et. al.* 2015].

A pool of 240 subjects was exposed to a library of waveforms consisting of example signatures of low boom aircraft. The signature library included intentional variations in both loudness and spectral content, and were auralized using the Gulfstream SASS-II sonic boom simulator. Post-processing was used to quantify the impacts of test design decisions on the "quality" of the resultant database. Specific lessons learned from this study include insight regarding potential for bias error due to variations in loudness or peak over-pressure, sources of uncertainty and their relative importance on objective measurements and robustness of individual metrics to wide variations in spectral content. Results provide clear guidance for design of future large scale community surveys, where one must optimize the complex tradeoffs between the size of the surveyed population, spatial footprint of those participants, and the fidelity/density of objective measurements.

As seen in Figure 6-8, it was found that the lower 10% of participants were highly sensitive to objective uncertainty. This causes us to focus on reducing the objective uncertainty of the low boom measurement associated a given response to as low a value as possible.

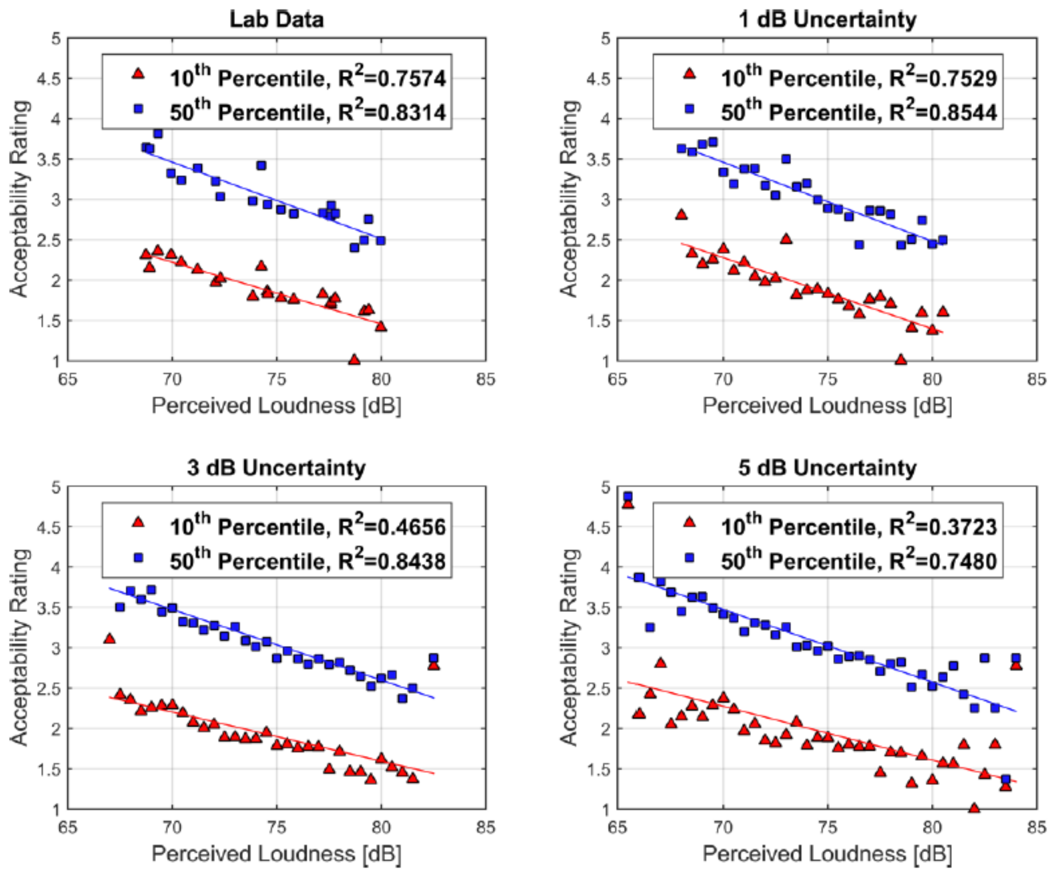


Figure 6-8 Discrepancy between an objective measurement and subjective response

[Collmar et. al. 2015]

In an effort to determine the number of noise monitors that would be required for correlation with subjective response, a simulation was constructed with the following assumptions:

- All recruits lived in a random distribution in a 40x50 mile domain
- No "community centers" were identified, individuals did not "cluster"
- Recruits commuted in random directions an average of 25 minutes from home (based on U.S. Census data) – for the purpose of the simulation this was translated to random distances from 0 to 15 miles for all participants
- The sonic boom carpet was ideal and symmetrical, neither winds nor turbulence were considered. This is not expected in a real test but rather only for the purposes of this simulation.
- Recruits that commuted outside of the region were omitted from the calculation of the standard deviation

Given the mobility of the recruits, it was determined that attempting to associate recruits with noise monitors located near their home introduced greater than 3PLdB uncertainty in the noise to which they were exposed as seen in Figure 6-9. It was found that localizing recruits to noise monitors distributed across the area resulted in their distance being less than half of what their distance would be if their response was associated with a dose measurement attained from a noise monitor at their place of residence as shown in Table 6-2.

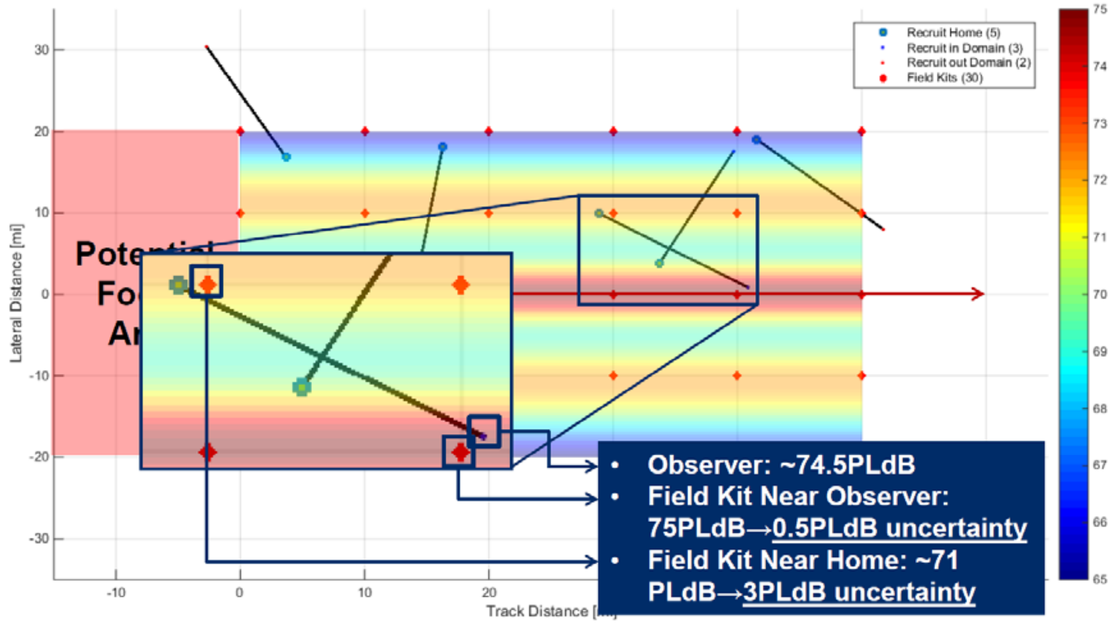


Figure 6-9 Uncertainty resulting in association of a recruit with noise monitors near their home

Table 6-2 Comparison of Mean Distances
Between Observer and noise monitor at their residence versus GPS based proximity noise monitor.

Recruits	Mean Distance b/w observer and address based proximity mic [mi]	Mean Distance b/w observer and GPS based proximity mic [mi]
50	8.425	3.712
100	8.409	3.722
200	8.485	3.725
400	8.417	3.708
800	8.450	3.711
1600	8.454	3.714

This further confirms the need to localize subjective respondents through survey design and permitted cell phone location services.

An analysis of the number of recruits with a uniform distribution of 30 noise monitors is shown in Table 6-3. The objective uncertainty of the noise exposure for each recruit was determined from which the Mean Objective Uncertainty was calculated for six populations of recruits, increasing in size from 50-1600. The 95% Confidence Interval for each of these populations is based on the standard deviation of the uncertainty measurements and the sample size; it is a reflection of the interval around the mean which can be relied upon to contain 95% of the responses. This revealed that sample size drives the confidence interval whereas mean uncertainty is not significantly affected.

Table 6-3 Sample size (number of recruits)

Recruits	Mean Uncertainty [PLdB]	95% Confidence Interval [PLdB]
50	0.3291	±0.3192
100	0.3525	±0.2229
200	0.3425	±0.1558
400	0.3339	±0.1099
800	0.3454	±0.0777
1600	0.3341	±0.0548

Noise monitor density was further explored as shown in Figure 6-10. For this analysis the number of recruits was fixed at 600 and the density of microphones was evaluated increasing the density by recursive subdivisions with an offset ($4N^2$-N). The results of this analysis as presented in Figure 6-11 Ultimately the number of microphones could be increased to the point that there is one co-located with each recruit which would be ideal, however given the cost of noise monitors and the effort associated with their deployment this is not feasible. The results indicate that for 600 recruits in an area of 40x50 miles the number of microphones required to minimize uncertainty within an acceptable 95% confidence interval is approximately 100-200 microphones. This is helpful in determining both noise monitor density as well as the scope of our recruiting efforts.

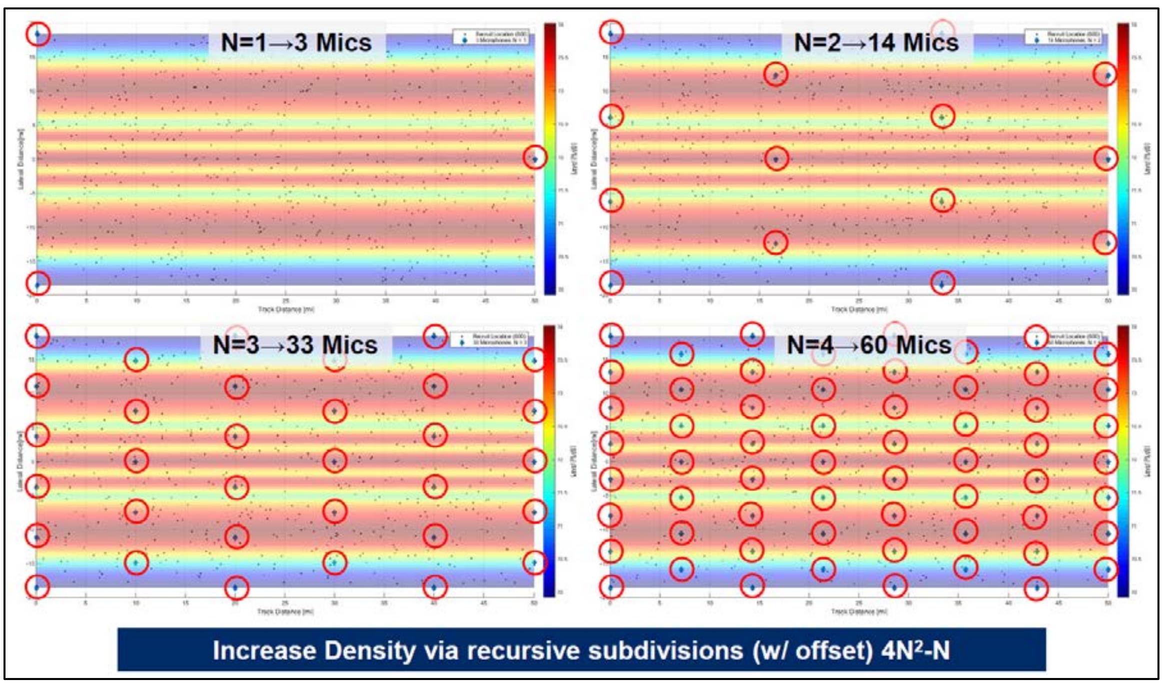


Figure 6-10 Noise Monitor Density Analysis

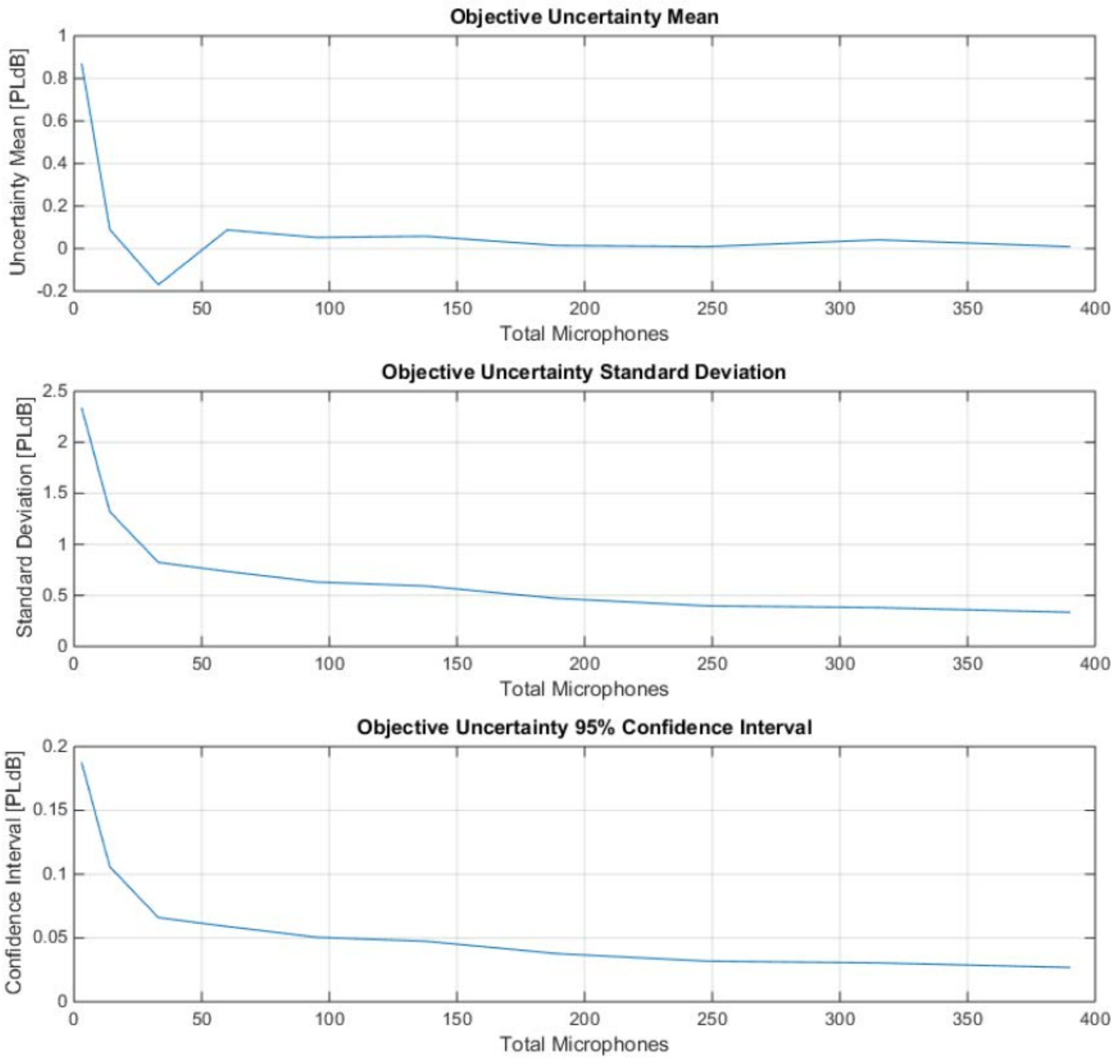


Figure 6-11 Noise Monitor Density Statistics

This analysis accounts for recruit's mobility and the distance they may be from the nearest noise monitor provided that we can localize them sufficiently. This additionally indicates the need for noise monitors to be multi-purposed, for example noise monitors configured for the detection of turbulence or to characterize the boom carpet must additionally supplement those noise monitors placed specifically for correlation with the community response. Additionally we will need to be aware through the recruitment process and the proximity of communities to edges of the boom carpet to identify recruits that could possibly exit the area.

Our current approach for the placement of noise monitors can be summarized as:

1. Ensure effective placement of monitors where respondents are expected to be during the test
    a. Locate 2+ monitors at the flight track entry and exit of the community area
    b. Locate 3+ monitors in the center of the community area
    c. Locate 1+ monitor in highly populated areas

Figure 6-12 depicts this approach using Orlando Florida. Monitors are separated by approximately 1 to

1.5 miles with an additional monitor placed downtown Orlando near City Hall. Ideally for security purposes these monitors would be placed on the grounds of public facilities such as Police, Fire, or Public Works.

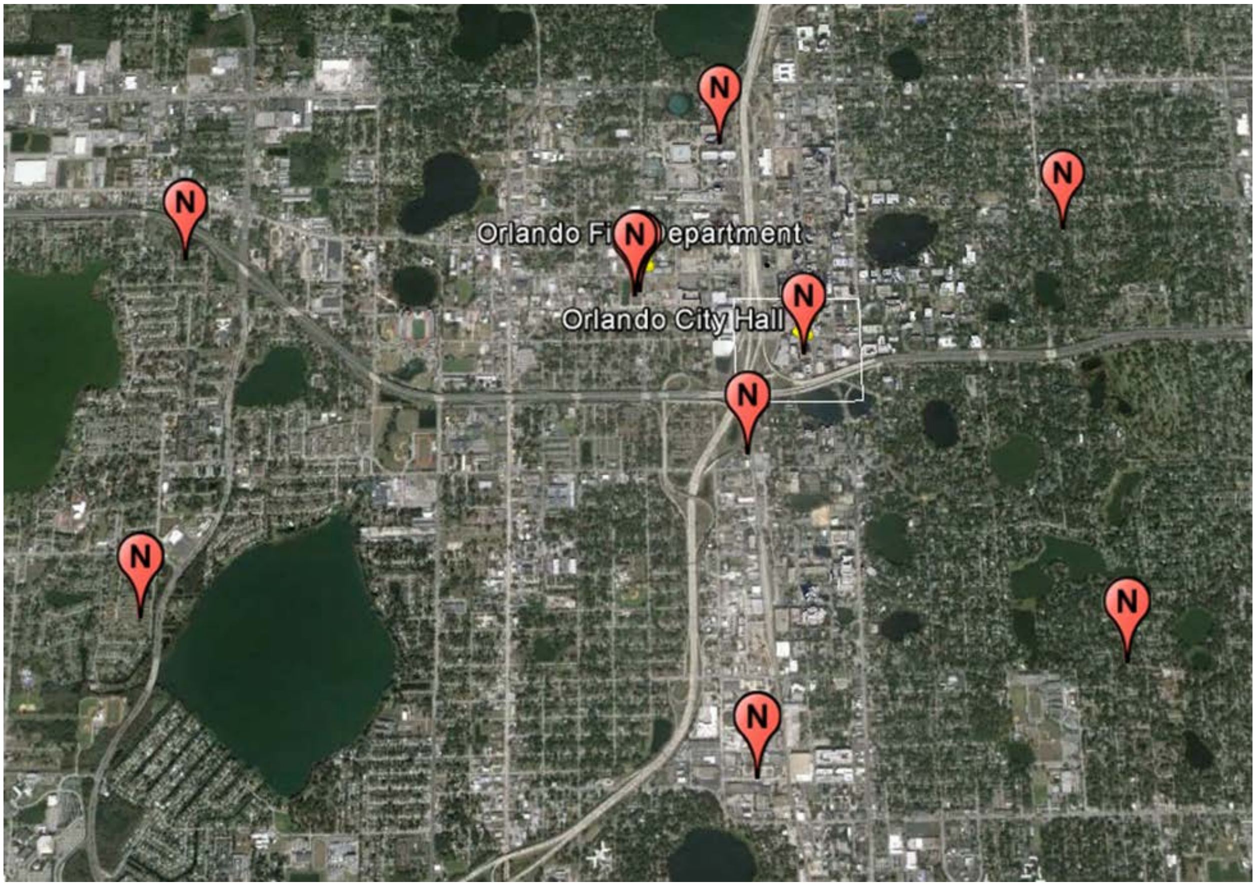


Figure 6-12 Hypothetical noise monitor distribution for correlation with subjective response

Monitor separation is 1-1.5 miles, with additional monitor positioned central to downtown near Orlando City Hall and near the Fire Department for the detection of Turbulence (see section 6.4.4)

6.4.2 Focus and Climb Region Instrumentation requirements

Determination of the focus and climb regions are only necessary to ensure that they do not encroach on the carpet region in which the respondents will be located. The planned flight trajectory is designed to put the focus and climb region over water and only have the constant-speed portion of the trajectory's boom footprint on land, then a minimal set of resources will be required to monitor the land/sea interface to ensure this phenomena did not encroach onto the carpet region.

6.4.3 Flight Path/Carpet Region Instrumentation Requirements

The Carpet Region has two aspects: the footprint along the length of the flight path trajectory and the behavior of the footprint laterally from the flight path out to and beyond the lateral cutoff due to atmospheric refraction. To verify that the desired footprint was achieved along the length of the trajectory, monitors need to be placed along the ground track. Noise monitors will be placed perpendicular to the ground track in order to measure boom signatures out to and beyond the lateral cutoff. Deploying such an array to both sides of the ground track should be done since symmetry in the lateral extent, signature shapes and amplitudes of the boom footprint cannot be assumed due to atmospheric conditions.

Flight track monitors shall consist of five monitors at entry of the predicted carpet region, five at the exit, and seven at midpoint (Figure 6-13):

- *Entry:* 1 monitor along the flight track and two distributed to each side of the ground track
- *Exit:* 1 monitor along the flight track and two distributed to each side of the ground track
- *Midpoint:* 1 monitor at the midpoint, 3 monitors distributed to each side of the ground track

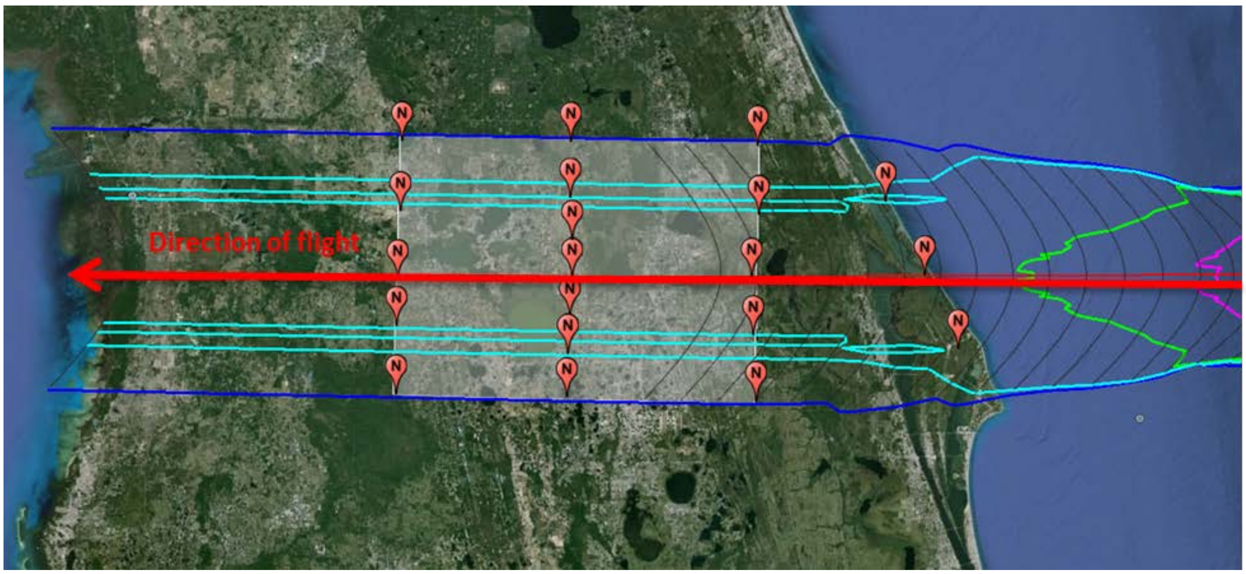


Figure 6-13 Flight Path Carpet Region Instrumentation Requirements

(The three easternmost sensors are intended to verify that there is not any encroachment of the focus/climb booms upon the carpet region.)

6.4.4 Instrumentation for Detection of Atmospheric Turbulence

Atmospheric turbulence can significantly affect the noise perceived by subjective respondents. We will monitor environmental measurements and forecasts to predict when and where atmospheric turbulence may occur relative to the locations of our respondents. Past experiences has shown that noise monitors will be arranged in an L configuration separated by 100 feet will indicate the presence of turbulence via the peaking and rounding of the boom signatures. Such an arrangement will be deployed in the vicinity of where respondents are anticipated to be located as shown in Figure 6-14.

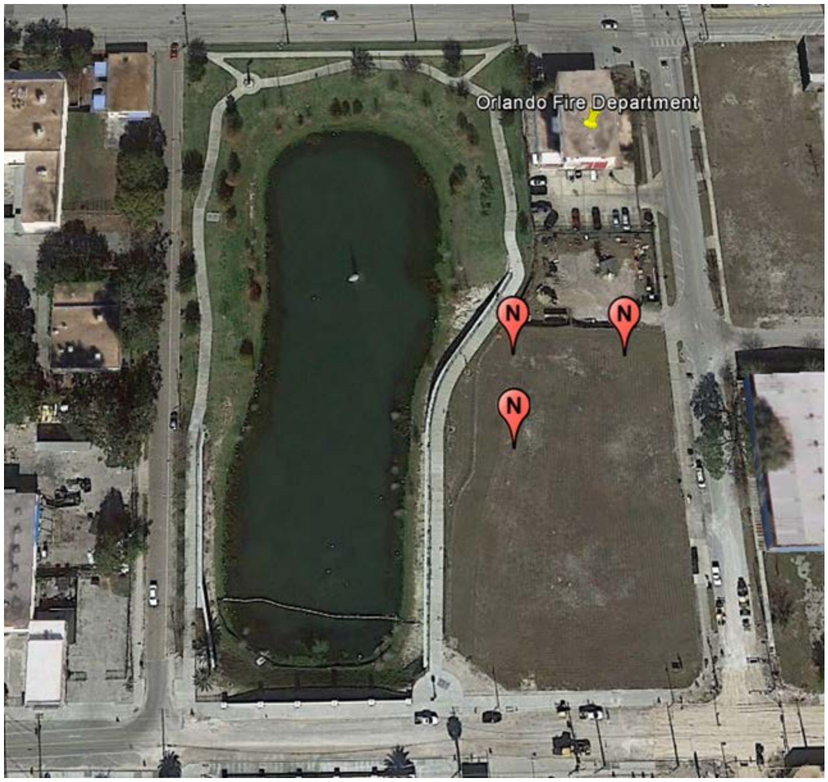


Figure 6-14 Noise Monitor Placement for Detection of Turbulence

The purpose of these monitors is to determine whether or not the respondents were subjected to enhanced boom effects due to turbulence. These noise monitors can serve multiple purposes in that they can detect turbulence and additionally collect objective measurements for correlation with subjective responses. The total number of noise monitors configured in this manner will depend upon the distribution of our subjective respondents and the environmental variability across the carpet region. At a minimum, each community center within the carpet region will have at least three monitors in this configuration.

6.4.5 Additional Instrumentation Requirements

Noise monitoring equipment will be utilized to record the time varying background level for the duration of the experiment at each monitor location. Approximately one minute of data will be recorded hourly. This would allow us to directly obtain the background levels and spectra and use them in determination of noise dose rather than relying on background immediately preceding the boom or on population density or traffic based background noise models. This data will also facilitate the evaluation of correlations of dose-response with background noise characteristics. We will investigate adjustment of background noise as a function of the respondent geographic/location information.

Additional noise monitors will be utilized in the vicinity of respondent anticipated locations and highly populated areas which could potentially receive complaints. Additionally atmospheric and topographic variability may warrant relocation or deployment of additional sensors. Figure 6-15 presents a good example of a complex city center (Orlando) which is typical of what will be encountered over the course of LBFD test deployments. As an active center where multiple respondents can be anticipated, multiple noise monitors would be warranted to assess the urban canyon effects and their relationship to subjective response. In a setting such as this it would be worth considering placement of noise monitors on the tops of the larger buildings which offer flat surfaces as well as on the ground in some of the narrow streets as well as open areas. The urban canyon propagation effects are something that should be considered. Further discussion of this is provided in Section 10.

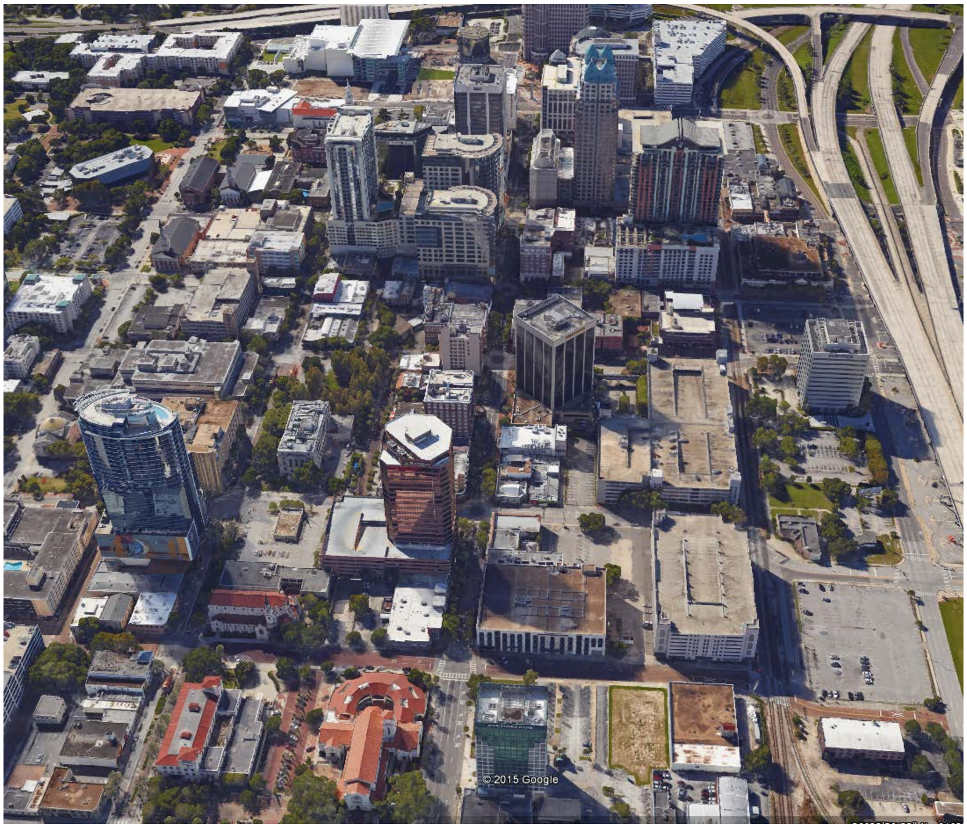


Figure 6-15 Orlando City Center

(North is the towards the bottom of the image)

7. Recruitment

7.1 Recruitment Techniques

The target for the LBFD would be 1000 respondents under the flight path in each of the six sites located in geographically distinct regions. Participants will be recruited from communities under the flight path. The recruitment will include urban and rural communities selected from across the six regional geographic sites. The address based sampling (ABS) approach is proposed to remain in compliance with The Telephone Consumer Protection Act (TCPA), which requires telemarketers to obtain prior express written consent from consumers. The TCPA requires express prior consent to use an automatic telephone dialing system (autodialer) to call cell phones. The FCC does not exclude research calls but the ruling has clearly restricted the use of autodialers to call wireless phone numbers. In the TCPA Omnibus Declaratory Ruling and Order FCC-15-72 , the TCPA defines 'automatic telephone dialing system' as "equipment which has the capacity—(A) to store or produce telephone numbers to be called, using a random or sequential number generator; and (B) to dial such numbers…" The ruling further states "if a caller uses an autodialer or prerecorded message to make a non-emergency call to a wireless phone, the caller must have obtained the consumer's prior express consent or face liability for violating the TCPA. Prior express consent for these calls must be in writing if the message is telemarketing, but can be either oral or written if the call is informational" (FCC-15-72).

Survey research firms have changed their approach to accommodate this ruling. The marketing research organization further outlined the risk of autodialing. They indicated that dialing "accidents" are not an effective legal defense and penalties run from $500 to $1,500 *per violating call* [Feinberg, 2015]. Feinberg further points out that "trial lawyers in recent years have discovered that researchers are a lucrative target for TCPA class action lawsuits, as evidenced in the recent $12 million TCPA settlement agreed to by Gallup [Feinberg, 2015]." The use of ABS as a recruitment approach is being implemented to address and avoid the risks presented by this recent FCC ruling.

To address the increased liability risk presented by this FCC ruling the Marketing Research Association compiled suggestions for researchers to help minimize their legal liability. As cited in Feinberg, the recommendations to address the new TCPA regulations are:

1. Only call/text cell phones using an autodialer with the respondent's express prior consent;
2. Manage the risk of using an autodialer to call/text cell phone numbers with the respondent's express prior consent, because such numbers may have been reassigned to different subscribers for whom express prior consent does not exist;
3. Aggressively scrub cell phone numbers for which you do not have express prior consent from your autodialer databases and maintain a do not contact list; and
4. Keep impeccable records.

7.2 Recruitment for Survey Participants

Once the target areas for boom analysis are determined and the demographic distribution of the community is assessed, we will sample from the population utilizing a targeted Address Based Sampling (ABS) approach. Address Based Sampling provides a high level of household coverage for representative sampling. Some estimate as high as 98% of the addresses of households in a community can be reached by ABS [Messer & Dillman, 2011]. ABS samples are based on the USPS Delivery Sequence File, which is regularly updated based on postal carrier reports. Vendors such as Survey Sampling International and Marketing Systems Group, through proprietary practices, append names, phone numbers and a variety of other factors (i.e. number of children) to addresses purchased. As many as 85% of addresses can be appended with the name of householder, and between 35 to 50% can be appended with phone number and additional information if additional contacts will be needed.

To insure representation of potentially underrepresented populations, for example based on ethnic or racial background, or income status, oversampling in those areas where there is a higher concentration of population members who meet the underrepresented status, can increase the likelihood of their participation. Using a weighting strategy post-data collection that takes into consideration the sampling distribution would be required to insure the data are as representative as possible.

Towards a goal of reaching 1000 respondents that will complete the pre-survey and participate in the single-event and End of Day surveys, the recruiting strategy will utilize a Tailored Design Method [Dillman, Smyth and Christian, 2009] approach to 4000 homes in that targeted area. A complete enumeration of households will be conducted within a predetermined distance from installed noise monitors across the community. A random sample of households will be selected for recruitment using Address Based Sampling (ABS). In areas with sufficient population density, a systematic random sample will be selected by determining a random starting point on the enumerated list of available households and using a sampling interval. The interval would be based on the ratio of required respondents to the total number of available households in that area. For each household recruited, we would ask for the person over 18 years of age with the most recent birthday to identify the resident that would participate. The contact interview would ensure that the respondents both lived and worked in an area under the intended flight path.

7.3 Initial Mailing and Baseline Survey

The initial mailing and baseline survey will follow the principles of the Total Design Method (TDM) as developed by Don Dillman. The TDM relies on the tenets of social exchange theory and is designed to both reduce respondent burden and increase likelihood of response. With attention to design and increased points of contact, a well designed and implemented survey using the TDM is capable of obtaining response rates between 20% and 45% in a general population. Comparable representative phone surveys using Random Digit Dialing (RDD) generally get between 7% and 10% response rates.

The first element of the design is a well formatted and easily readable survey. Following the guidance of the best practices for questionnaire design, the baseline survey will be carefully constructed to be both concise and accessible by a general population. To achieve this, the survey should not take any longer than 15-20 minutes to complete and should be written to target an 8th grade reading level. Once the final concepts are determined, the Survey Research Center will assist with the wording and formatting of questions. The questionnaire will be programmed in both printed format, using Cardiff Teleform for scannable surveys, as well as being formatted in a mobile enabled web platform, Qualtrics. The printed survey will not exceed 12-pages in length, and will be printed in booklet format. The mobile enabled form will implemented using Qualtrics, a web based survey software tool.

Following the TDM, the baseline survey will include up to 4-points of contact with potential respondents. This includes 1) a pre-notification letter; 2) an initial printed survey mailing; 3) a post-card reminder; and 4) a final survey mailing.

7.3.1 Pre-Notification Mailing

After the geographically targeted sample has been purchased and the instruments have been programmed into the scanning software and mobile enabled web platform, we will print and mail a one-page introduction and invitation to participate letter. The letter will include information on the nature of the survey instruments, as well as the process of data collection. It will include information, including a secure ID for login, for respondents to complete the contact survey via mobile enabled web platform. The introduction and invitation will include basic consent language, which will be expanded upon in the instruments themselves. The contact survey will provide on-line contact information (email and mobile phone), consent to contact via phone or email, and work address to ensure respondents both lives and works within the expected boom carpet. The pre-notification mailing will be sent to the 4000 sample names and will be timed to be sent approximately 1 week to 10-days prior to the initial mailing. This will allow for any return of bad addresses as well as any initial web completions. Bad addresses will be supplemented with new addresses, and those who complete via the web contact survey will be removed from any subsequent mailing. Each sample address will be assigned an ID number that will be used by the SRC for tracking purposes. All correspondence will include the ID number as well as the potential respondent name (when possible). Final data will only include ID number and identifiable information will only be used for tracking purposes and will be kept in a secure location and accessible only by the SRC.

7.3.2 Initial Survey Mailing

Approximately 1 week to 10-days after the pre-notification, the SRC will prepare and send the initial baseline survey mailing. The initial survey mailing with be sent to up to 4000 sample participants, with those who have completed on-line contact survey removed. Subsequent correspondence with established contacts can be done on line or by phone. The initial baseline survey mailing will include an introductory letter that includes information on how to complete the survey on-line, a printed copy of the survey, a business reply envelope, and a token $5 incentive. One of the key principles of the TDM is the idea that token incentives can provide added motivation for respondents to participate in a survey. A small pre-incentive of $5 can increase response rates as much as 10 to 15%. All documents will be clearly written at an 8th grade reading level and will include several points of contact if there are any questions or concerns. Once the initial mailing has been sent, the practice is to wait 1 week to 10-days for responses to return, before sending the reminder postcard. As responses come in via business reply envelope or web survey, they will be recorded daily and databases will be updated to indicate who has responded and who has not. Completed paper surveys will then be processed, scanned and verified.

7.3.3 Reminder Post Card

Approximately 1 week to 10-days after the initial survey mailing, a reminder post card will be sent to all sample addresses. The post card will remind the respondent that we recently sent them a survey, thank them for their participation if they have completed, and let them know how to request another survey or more information if they have misplaced or not received the initial survey.

7.3.4 Final Survey Mailing

Approximately 1 week to 10-days after the reminder post card, a final survey mailing will be sent to all non-respondents according to the daily updated data base. The final survey mailing will include a paper version of the survey, as revised and encouraging letter, including information on how to complete on-line, and a business reply envelope.

Approximately 2 weeks to 20 days after the final mailing, the survey will be deemed "closed" assuming all those who have chosen to complete will have done so by that time. The data collected and scanned from the paper surveys will be merged with the data collected via the web surveys and a clean data set will be assembled for analysis. Those who have completed the baseline survey will be asked at the conclusion of the survey if they would be willing and able to participate in the more intensive end of day survey and event surveys. The response rate [Messner, *et.al.* 2011] cannot be guaranteed, but is anticipated to be 25% to 40%, which should provide up to 1000 to 1600 potential participants in the subsequent surveys.

8. Test Execution

8.1 Pre Test Requirements and Activities

A series of assessments with NASA and other established review boards will be conducted, implementing the following protocols, to ensure that the test is in compliance with regulatory guidelines, safety requirements are met, and the day of test conditions are acceptable to meet the project objectives and support a successful test. This implementation will ensure that the necessary data is captured while within these previously established guidelines.

Prior to conducting the test, both Office of Management and Budget (OMB) and Institutional Review Board (IRB) approval will be obtained. Since the research proposed involves the use of human participants, an application must be submitted and approval granted by Office for Research Protections (ORP) Institutional Review Board (IRB) before the experiment can commence.

The OMB paperwork will be developed by researchers at Penn State, and NASA will submit the forms to OMB for review. The approval process follows:

1. Prepare the Information Collection document according to OMB specifications;
2. Develop the required Paperwork Reduction Act supporting statements;
3. Publish a notice in the Federal Register providing a chance for any interested individuals to comment on the proposed information collection within 60 days;
4. Prepare the final Paperwork Reduction Act submission, including any public comments received, to OMB;
5. Receive OMB approval or disapproval for the information collection.

Researchers at Penn State ARL and SRC are responsible for preparing the Institutional Review Board (IRB) application on behalf of the WSPRRR team and ensuring compliance with the requirements of the PSU IRB. They will then submit the required IRB associated information for NASA IRB review. All members of the research team involved in the design, conduct, data analysis, or reporting of the research must complete training. The training that is offered through the Collaborative Institutional Training Initiative at the University of Miami (CITI) is in compliance with both the PSU and NASA IRB training requirements. The CITI site can be accessed at http://www.citiprogram.org/. When selecting the institution, choose Penn State University as applicable to your affiliation.

After the OMB and IRB approval have been secured, initial site visits will commence in order to coordinate with the NASA flight test crew, scout community noise monitoring sites and solicit cooperation from community leaders.

Social media monitoring will be implemented as pro-active Outreach, as described in Section 3.4. Social media monitoring tools that can monitor posts in a defined geographic area will be used to observe responses on social media in test communities for 1 week before the test begins. Monitoring the week before the test allows us to observe if there are any relevant issues within the community at the time of the test. These issues could be existing concerns about noise, or any pre-test on line discussion of our upcoming field test.

8.2 Day of Flight Activities

Daily flight planning will be conducted by NASA. During WSPR, these activities included computation of the F-18 waypoints based on the most recent GPSsonde upper air meteorological data. Daily flight planning also included an assessment of the best flight cards to be flown depending on the atmospheric conditions. Our noise dose design has included flexibility to allow for day of flight variations. More detailed criteria will be implemented by NASA DFRC pilots and operations personnel and are not reported here.

8.3 Go / No-Go Criteria

A Go/No-Go decision will be made by the NASA Principal Investigator prior to each day's testing, and prior to each flight. Development of new upper air criteria (maximum wind and temperature gradients and altitude bands) for successful F-18 Dive Footprint delivery will need to be established in Phase 2 in order to support tests in locations other than the EAFB area. A cursory examination of footprint sensitivity to historical upper air profiles may be found in Appendix B.

Flights will not occur in the event of the following:

1. Aircraft readiness or safety issues are not met, as determined by NASA
2. Weather
    a. As NASA Safety rules regarding cessation of flights for inclement weather dictate
    b. Upper Air Profile Footprint Delivery Conditions cannot be met
3. Communication system failure
    a. Air to Ground communications failure
    b. Significant percentage of instrumentation communications unavailable
4. Instrumentation failure
    a. Failure of flight instrumentation such that position and orientation information cannot be obtained or the aircraft cannot reliably perform the low-boom dive maneuver
    b. Excessive number of Field Kits channels not ready
    c. Failure to obtain initial (pre-flight) upper air data
    d. Widespread internet or Cellular wireless outage in the test community area

8.4 Subjective Design Features

A complete enumeration of households will be conducted within a predetermined distance from installed noise monitors across the community. A random sample of households will be selected for recruitment using Address Based Sampling (ABS). In areas with sufficient population density, a systematic random sample will be selected by determining a random starting point on the enumerated list of available households and using a sampling interval. The interval would be based on the ratio of required respondents to the total number of available households in that area. For each household recruited, we would ask for the person over 18 years of age with the most recent birthday to identify the resident that would participate. The contact interview would ensure that the respondents both lived and worked in an area under the intended flight path. The full recruitment is described in Section 7.

8.5 Objective Measures

The Sonic Boom Unattended Data Acquisition System (SBUDAS), also known as Sonic Boom Field Kits, were the primary sonic boom recording systems for the WSPR experiment. These kits will again serve as noise monitors recording low booms for metric analysis. In addition, Commercial off the Shelf (COTS) components have been identified that can be integrated to support Low cost monitoring systems to augment the field kits, providing additional coverage across the region. Section 6 details these monitors and their planned deployment for effective measurement of the low boom. Monitors would be distributed across the region in areas where recruits lived and worked.

8.6 Leveraging ASCENT

As part of the ASCENT sponsored Supersonics effort, researchers are assessing low boom metrics, and investigating optimal approaches to monitor boom impact. One approach is the use of social media monitoring implemented in a form of pro-active Outreach as described in Section 3.4. The monitoring of social media is the equivalent of a soft sensor implemented to alert us to extreme events (an unexpectedly loud boom impact) and to observe reactions within the community. The monitoring would be conducted throughout the field test, and for 1 week after the test. The comments on social media could provide insight into a reaction to a boom impact that we didn't anticipate. On-line observation of public domain comments will allow our team to quickly address concerns with a proactive press release, taking prompt action to contain any potential viral negative media.

Both elements of the leveraged program are critical to this proposed research. Our proposed metrics currently parallel the metrics being investigated on the ASCENT effort. The outcome of the ASCENT metrics investigation will further inform our metric selection. Our field test will provide data that can assess the single event and daily metrics recommended from the ASCENT effort, providing synergy across the FAA ASCENT and NASA WSPRRR efforts. Any critical issues and gaps identified during the ASCENT metrics assessment can be addressed during the adaptation of the metrics evaluated under this NASA research program.

9. Data Analysis and Anticipated Results

9.1 Acoustic and Atmospheric Data Post-Processing

This section addresses analysis of atmospheric and acoustic measurements collected during each LBFD Test Deployment.

9.1.1 Acoustic Sensor Fidelity

As described in section 6.1.2 low cost noise monitors are being considered in the interest of fielding a greater number of sensors across the large carpet region. Qualitative measures of boom signatures require a system response that is flat from 0.1 Hz to 10 kHz; the low end is the feature that makes them costly. System costs are reduced as the low frequency requirement is relaxed however this impacts the ability for full reproduction of the boom signature, most notably the measurement of peak overpressure (Δp). As shown in Figure 9-1, the microphones being considered for low cost noise monitors are expected to have a flat frequency response curve down to approximately 5 Hz at which point it will significantly degrade.

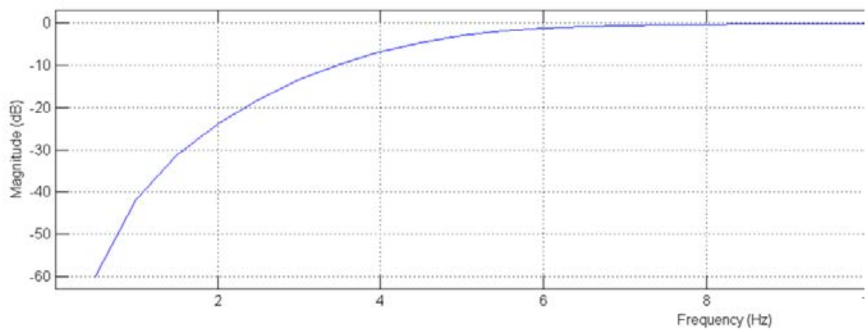


Figure 9-1 Response Curve for a 3 pole high pass filter (Butterworth Matlab) showing -3dB at 5 Hz

We have investigated the effect of this on recorded booms as seen in Figure 9-2. It is clear that the signature has lost its N-wave character and shock amplitudes are reduced using a 5Hz High Pass (HP) filtered microphone.

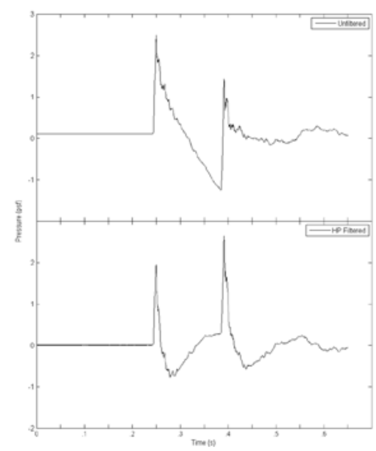


Figure 9-2 Recorded Boom (top) High Pass Filtered result (bottom)

These outputs are consistent with results published in the Journal of the Acoustical Society of America (Hilton et. al. 1966) as shown in Figure 9-3.

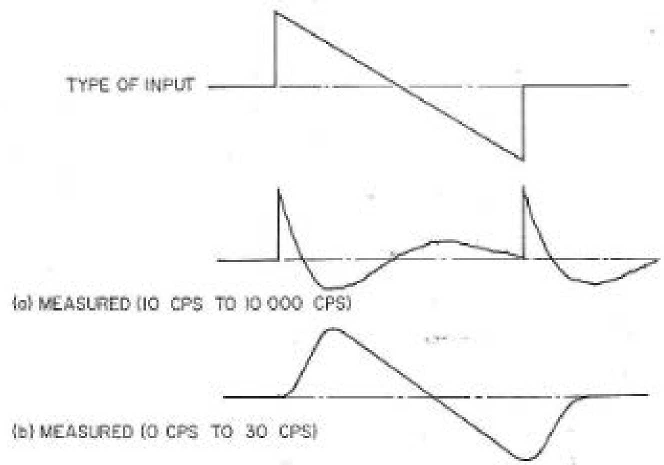


Figure 9-3 Effects of over-all system frequency response on a sonic boom pressure signature

We are investigating the potential of extending the low frequency response of the microphones being considered for the LCNMs by applying methods described by Timothy Marston in his thesis “Diffraction Correction and Low Frequency Response Extension for Condenser Microphones [2006]."

The basis of the methodology is that a transfer function correction can be determined based on calibration of the LCNM microphone in a laboratory setting with a standard low frequency microphone. Martson determined that the correction, computed such that the non-low frequency microphone signal matches that of the low-frequency microphone, remains applicable for future low-frequency corrections of that system. He summarizes by stating that “as long as the transfer function relating the two microphones remains time-invariant, the code should be able to compensate for the roll-off” in the microphone to correct the waveforms. Analysis would be required to determine if there are system to system and microphone to microphone variations, for matching system and microphone types, which would require correction factors to be determined for each individual system. Other considerations would have to be explored, such as effects of microphone calibration, on the correction factors. Provided that such system specific variations do not exist and considering that the low boom footprint is anticipated to be largely uniform, it is hoped that this method would allow the transfer function to be calculated from a small subset of LCNMs collocated with SBUDAS field kits and then be utilized for signature recovery from all other LCNMs utilized in the LBFD Test Deployment. An experiment is recommended as a Phase 2 activity beyond the originally proposed scope in Section 12.

While these noise monitors may or may not reproduce the boom signature their primary purpose is to measure noise metrics (PLdB in particular) and to provide an indication of the existence of turbulence. LBFD future vehicles will have shaped signatures with rise times of 20 msec. These rounded shapes as peak amplitude is reached will result in low values of PLdB as well the signature being less influenced by turbulence.

Most boom metrics are weighted to the higher frequencies that also define shocks. A comparison of the noise metrics computed from both of the signatures in Figure 9-2 indicates consistency for all metrics with the exception of FSEL as shown in Table 9-1. It is expected that the Low Cost Noise Monitors described in Section 6.1.2 Low Cost Acoustic Instrumentation, will measure PLdB within 1dB of the actual value.

Table 9-1 Noise Metrics Comparison

Metric	Recorded Boom	Filtered Version
PLDB	108.7	108.7
ASEL	88.9	88.9
CSEL	109.7	109.7
FSEL	119.0	117.0
PNL	115.1	115.1
ZDBO	115.9	115.9
ZDB1	116.3	116.3

Turbulence influences the higher frequencies of shocks in the boom signatures. Figure 9-4 shows the presence of turbulence in the comparison two signatures recorded using a condenser microphone with a flat response from 10Hz-7000Hz. The top signature was recorded at Wallops Island VA, where turbulence were not present. The bottom signature was recorded at Indian Springs NV during the afternoon using the same type microphone and the presence of turbulence is clearly visible in the signature.

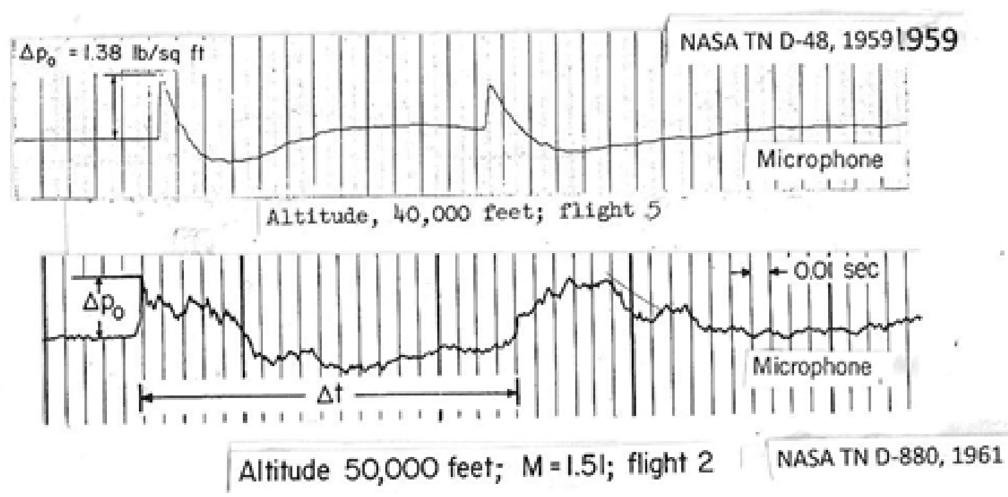


Figure 9-4 Two sonic boom signatures measured using a condenser microphone

Flat response from 10Hz-7000Hz. [Maglieri and Hubbard, 1959 and 1961]

This would indicate that the frequency response associated with the recommended Low Cost Noise Monitors should be sufficient to indicate the presence of turbulence.

9.1.2 Background Noise

WSPR 2011 explored the issue of how to address ambient noise when the metrics calculated for ambient noise are close to that of sonic booms. If the ambient levels were not at least 1 dB less than the boom metric, then that particular recording was considered too contaminated to use for further analysis. It was determined that if a boom is lower in amplitude and has energy comparable to the ambient, then the only way to remove the ambient energy from the metric calculations is to subtract it from the energy spectrum before calculating the metrics. The LBFD is anticipated to provide a single boom with such amplitudes and will therefore be handled accordingly through post processing of the measurements and subsequent calculation of the metrics as done previously in WSPR 2011.

9.1.3 Determination of Noise Dose and Metric Values at Participant Locations

It is anticipated that the regulatory community is seeking to establish a single metric and regulatory threshold level rather than separate metrics and thresholds for indoors and outdoors. Our team is taking the approach that outdoor boom measurements will be sufficient to correlate with response. The response "control volume" includes both the human plus the building element, with the input stimulus described by the outdoor sonic boom metrics. Given the uncertainty created by the wide variety of building types, the participant's location within a building, the impractical nature of such precise dose identification, and leveraging the very close correlation between indoor and outdoor metrics demonstrated in the WSPR 2011 project and others[§] our design employs only outdoor metrics of noise at a Participant's location for dose-response correlation for the LBFD Test.

In our approach: If a participant hears a boom at a noise monitor's location (within 25 feet), then the metrics calculated from the monitor's recording will be used to define that participant's exposure for that event. In the likely case where this is not true and the participant reports hearing a boom further than 25 ft. away from the nearest noise monitors, then the estimate of the metrics at the participant's location will be determined based on a combination of first and foremost the noise measurements in the vicinity, secondly the statistical variance of turbulence across the carpet region and lastly predicted levels generated using PCBoom and the environment measured at the time of flight. As described in Section 6.1, a combination of high-fidelity and low-cost monitors will be deployed in and around communities in the study area. The measurements at those locations capture the actual exposure.

Accounting for Turbulence Effects on Metrics at Participant Locations

Some studies conducted by the Environmental Science Services Administration (ESSA) during the 1966 EAFB National Sonic Boom Program sought to establish a more solid relationship between the atmosphere and its influence on sonic boom signatures. During these tests, it was observed that at the microphone array arranged in concentric circles out to a 100-foot radius (microphones 2 through 20) in Figure 9-5, the microphones that were within 25 feet of the center of the circle (microphones 4, 5, 9, 10,

[§] In the EAFB [Kryter, 1967] and Exercise Westminster tests [Webb & Warren, 1965; Johnson & Robinson, 1967] indoor & outdoor dose-response comparisons were made. For the EAFB tests only outdoor measurements of the boom were used when assessing the people's indoor responses [NSBEO, 1967]. Schomer, Sias and Maglieri [1997] found that "C- weighting is a useful outdoor measure for assessing the indoor community response to high energy impulsive sounds". Setting aside for now his "C" weighting, the point being made is that indoor responses should be correlated with an outdoor metric. Also Leatherwood *et al.,* [2002] point out that PLdB is "clearly a good metric for outdoor listening of booms and there is some indication that it worked quite well indoors."

11, 12, 13, 17, and 18) were correlated (i.e., all the signatures were essentially the same). As the distance from the center of the circle increased to 50 feet (microphones 3, 8, 14, and 19) the correlation ceased to exist and all the signatures were different from each other [Roberts *et. al* . 2014].

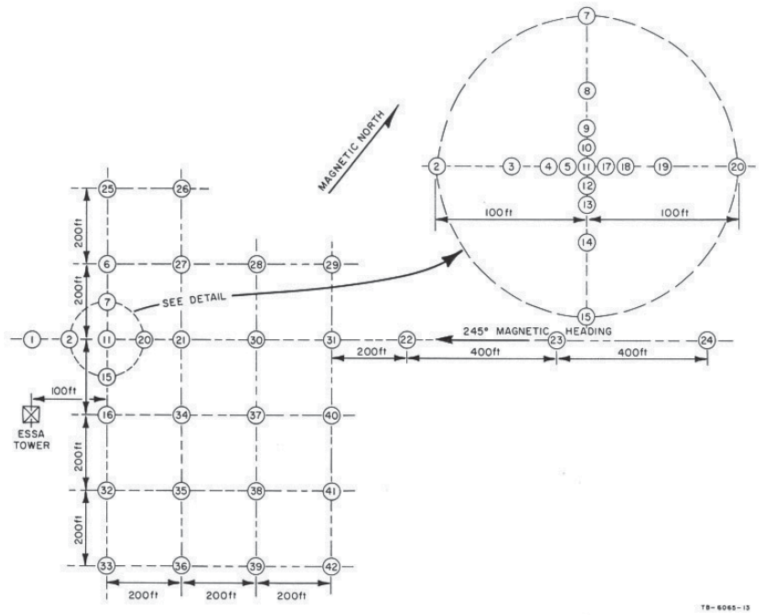


Figure 9-5 Microphone array for ESSA studies – Site 9

Low-boom shaped signatures are designed to be more resistant to the influence of lower layer atmospheric turbulence resulting in far less variation in Δp and PLdB. The turbulent process in the atmosphere is the result of some form of instability which produces random turbulent fluctuations in wind and temperature that can only be described in statistical terms [Maglieri *et. al.,* 2014].

Our approach will develop a grid of stochastic turbulence effects based upon environmental and signature measurements from monitors distributed across the carpet region as described in section 6.4(along and laterally to the flight track and across the communities). This grid can be utilized to refine the interpolation between measurements in the vicinity of the participant's location.

Leveraging ongoing NASA Turbulence Research: SonicBAT

We recognize that NASA research and investment in the SonicBAT program is quickly expanding our understanding, modeling capabilities and validation datasets of turbulence effects on sonic booms. Additionally SonicBAT will add to the knowledge base, an understanding of the upper air conditions which foster the development of turbulence spiking and rounding on measured ground boom signatures. Members of our team are engaged in the SonicBAT studies and will develop and validate numeric models that are capable of computing propagation of arbitrary boom signatures through a variety of turbulent structures. Flight tests will be conducted at three locations in the US in a variety of climates to obtain validation data. Results from the numeric model, finite impulse response (FIR) filters, will be used to expand the existing suite of FIR filters in PCBoom and provide a range of atmospheric turbulence and climate parameters for which stochastic perturbations in the sonic boom metrics can be determined. This future capability can be utilized in conjunction with the LBFD measurements to refine the interpolation process for obtaining metric values at participant locations.

Post flight, PCBoom estimates will be generated utilizing the measured environment and flight trajectory. In the event that a participant's location is sufficiently removed from any noise monitors then the metrics at their location will be based upon the PCBoom-based interpolation of the empirical measurements, adjusted using the grid of turbulence effects. As the turbulence predictive capability is improved the process for obtaining metrics at participant locations can be readily updated.

9.1.4 Atmospheric Data Analysis

In support of post flight data analysis we recommend the inclusion of high resolution numerical weather modelling for the low boom carpet region. Numerical weather models are run by NOAA and DoD to generate large scale synoptic forecasts for weather conditions. While these scales are generally useful for regional weather forecasting they are insufficient for modeling and analysis purposes on the scale of this experiment. Our team has had discussions with the Navy Research Laboratory, Monterey CA (NRLMRY) concerning the employment of the COAMPS On Scene (COAMPS OS™). This is a discrete implementation of this model utilized by the Navy for very small scale specialized operations. NRLMRY has established the infrastructure necessary for specific high resolution model runs to be executed for small targeted areas for focused periods of time. COAMPS™ is similar to other mesoscale numerical weather models, however this focused, high resolution application of the model is only available through COAMPS OS™.

The Coupled Oceanographic Atmospheric Mesoscale Prediction System (COAMPS™) is run at Fleet Numerical Meteorological and Oceanographic Center, Monterey CA, for regions around the world in support of naval operations. The model begins with "first-guess" gridded fields of atmospheric data, observations from aircraft, rawinsondes, ships and satellites are blended with these fields to generate the current analysis. For idealized experiments, the initial fields are specified using an analytic function and/or empirical data (such as a single sounding) to study the atmosphere in a more controlled and simplified setting. The atmospheric model uses nested grids to achieve high resolution for a given area; it contains parameterizations for sub grid scale mixing, cumulus parameterization, radiation, and explicit moist physics. Examples of mesoscale phenomena to which COAMPS™ has been applied include mountain waves, land-sea breezes, terrain-induced circulations, tropical cyclones, mesoscale convective systems, coastal rain bands, and frontal systems.

The COAMPS™ model domain typically covers a limited area over the Earth. The model grid resolution may range from a few hundred kilometers (synoptic scale) to approximately 100 meters. The actual dimensions applied depend on the scale of phenomena that the user is interested in simulating. The model dimensions can be set to produce any rectilinear pattern. In addition, it can be rotated to align with any surface feature, such as the terrain or a coastline. COAMPS™ can be run with any number of nested grids, with the requirement that the horizontal grid resolution in any mesh be one-third that of the next coarser mesh.

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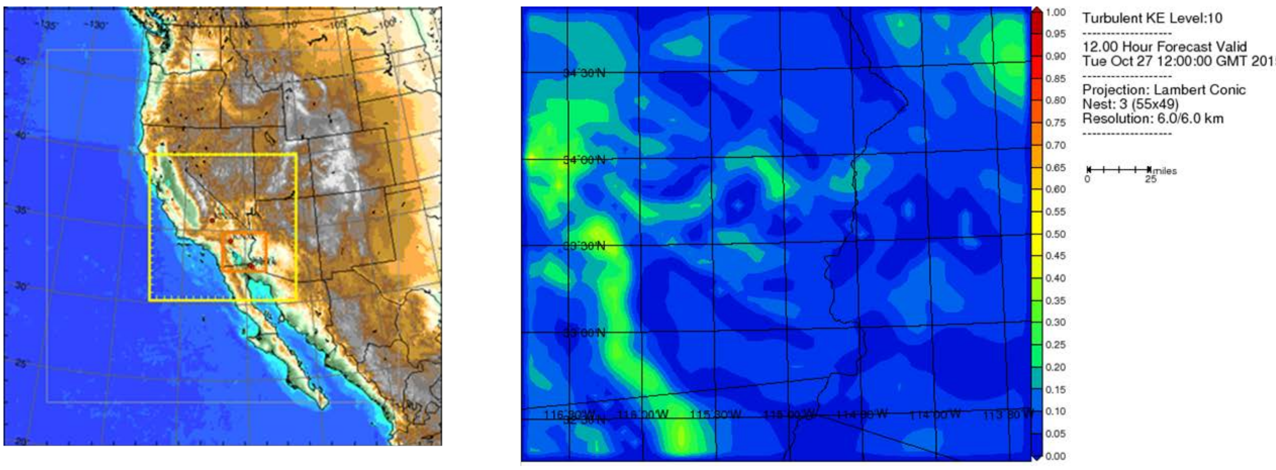


Figure 9-6 COAMPS Turbulent Kinetic Energy Forecast: 18km (left) and 6km (right) resolution

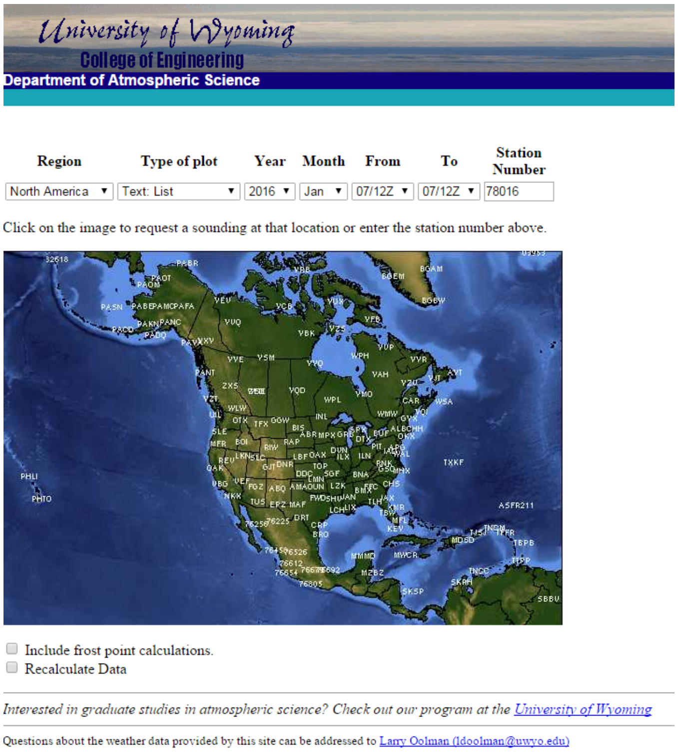
For our purposes we could arrange with NRL Monterey to instantiate a specific COAMPS OS™ run to cover our area of operations during the LBFD Test Deployment, this would be run at a finer resolution both spatially and temporally with the results archived to support post Test Deployment analysis.

Surface observations recorded through instrumentation distributed across communities as well as upper air observations collected on the day of the flight can be transferred to NRLMRY for assimilation into COAMPS OS™ runs. GRIB files of 30 minute forecasts for each parameter at all altitudes would be delivered daily via FTP for assessment of the forecast environmental variability across the area. This assessment would be useful in planning for environmental monitoring (e.g. number and location for GPSsondes along the aircraft track, or the forecast for atmospheric turbulence). All of the data would be archived and serve as a source of upper air profiles for post flight analysis providing highly resolved profiles, both spatially and temporally supporting PCBoom analytical runs. These numerical weather predictions will take into account the atmospheric soundings on the day of the flight as well as the full scope of measurement and forecasting across the region.

9.1.4.1 Regional Characterization Comparison

An objective of the LBFD Experiment will be the delivery of the same noise dose in each region to support comparisons of subjective response across all regions. All differences in the conduct of the experiment in each region must be noted in order to support this comparison between regions.

Prior to each LBFD Test Deployment, the environmental characteristics of the deployment site will be assessed. Both current and archived upper air observations (as far back as 1973) can be obtained from University of Wyoming [2016] (Figure 9-7) in a format that can be readily utilized in PCBoom [Page, Plotkin & Wilmer, 2010].



74794 XMR Cape Kennedy Observations at 12Z 07 Jan 2016

PRES hPa	HGHT m	TEMP C	DWPT C	RELH %	MIXR g/kg	DRCT deg	SKNT knot	THTA K	THTE K	THTV K
1015.0	3	17.8	17.2	96	12.31	320	8	289.7	324.4	291.9
1000.0	140	16.8	15.4	91	11.12	345	20	289.9	321.4	291.9
980.9	305	15.6	14.8	95	10.91	355	21	290.4	321.3	292.3
974.0	365	15.2	14.6	96	10.84	1	20	290.5	321.2	292.4
950.0	577	14.2	13.4	95	10.27	22	16	291.6	320.9	293.4
946.3	610	13.9	12.9	93	9.96	25	15	291.6	320.1	293.4
933.0	729	13.0	11.0	88	8.91	31	14	291.9	317.4	293.4
925.0	802	13.0	11.6	91	9.35	35	14	292.6	319.5	294.2
912.8	914	12.9	10.6	86	8.85	40	12	293.6	319.2	295.2
884.0	1183	12.8	8.1	73	7.72	18	7	296.2	318.9	297.6
880.3	1219	12.6	7.7	72	7.56	15	6	296.4	318.6	297.7
880.0	1222	12.6	7.7	72	7.54	15	6	296.4	318.6	297.7
850.0	1512	10.8	6.6	75	7.24	335	6	297.4	318.9	298.8
840.0	1611	9.8	5.6	75	6.83	333	8	297.4	317.7	298.6
828.0	1730	9.0	5.4	78	6.84	332	10	297.8	318.1	299.0
825.0	1760	9.0	4.7	74	6.53	331	11	298.1	317.6	299.3
819.0	1821	9.8	-4.2	37	3.44	330	12	299.6	310.2	300.2
818.2	1829	9.8	-5.8	33	3.05	330	12	299.6	309.1	300.2
816.0	1851	9.8	-10.2	23	2.17	330	12	299.9	306.8	300.3
804.0	1974	8.8	-9.2	27	2.38	328	13	300.1	307.6	300.5
795.0	2067	7.6	-2.4	49	4.05	326	14	299.8	312.2	300.5
788.6	2134	7.3	-4.4	43	3.53	325	14	300.2	311.1	300.8
780.0	2224	7.0	-7.0	36	2.91	321	13	300.8	309.9	301.3
759.9	2438	5.4	-4.2	50	3.70	310	12	301.3	312.8	302.0
757.0	2469	5.2	-3.8	52	3.83	307	12	301.4	313.3	302.1
752.0	2523	4.6	-4.4	52	3.69	302	11	301.3	312.8	302.0
735.0	2709	3.4	-5.6	52	3.44	283	10	302.0	312.7	302.6
732.0	2743	3.2	-4.7	56	3.71	280	10	302.1	313.7	302.8
724.0	2832	2.6	-2.2	71	4.52	270	11	302.4	316.4	303.2
711.0	2978	1.6	-3.2	70	4.27	253	12	302.9	316.1	303.7
708.0	3012	1.4	-3.0	73	4.35	249	12	303.0	316.5	303.8
704.9	3048	1.7	-5.3	60	3.68	245	12	303.8	315.3	304.4
700.0	3104	2.2	-8.8	44	2.82	240	13	304.9	313.9	305.4
695.0	3162	2.0	-11.0	38	2.39	243	13	305.3	313.0	305.7
690.0	3220	1.6	-14.4	29	1.83	245	13	305.5	311.5	305.8
674.0	3409	0.2	-14.8	31	1.81	254	14	306.0	311.9	306.3
669.0	3469	0.4	-22.6	16	0.94	256	14	306.8	310.1	307.0
661.0	3565	-0.7	-12.7	40	2.19	261	15	306.7	313.8	307.1
656.0	3626	-1.1	-11.1	47	2.51	264	15	306.9	315.0	307.3
653.3	3658	-1.1	-14.8	34	1.86	265	15	307.2	313.4	307.6
651.0	3687	-1.1	-18.1	26	1.42	266	16	307.6	312.3	307.8
629.0	3960	-3.5	-18.5	30	1.42	272	20	307.8	312.6	308.1
620.0	4073	-4.7	-18.7	33	1.42	275	22	307.7	312.5	308.0
610.0	4201	-4.9	-31.9	10	0.44	278	25	308.9	310.5	309.0
604.9	4267	-5.3	-31.2	11	0.47	280	26	309.3	311.0	309.4
596.0	4384	-5.9	-29.9	13	0.54	282	25	309.8	311.8	309.9
581.6	4572	-7.6	-30.7	14	0.51	285	23	310.1	311.9	310.1
559.1	4877	-10.3	-32.0	15	0.47	275	22	310.4	312.1	310.4
537.4	5182	-13.0	-33.4	16	0.43	280	21	310.6	312.2	310.7
532.0	5261	-13.7	-33.7	17	0.42	279	22	310.7	312.2	310.8
500.0	5730	-16.3	-42.3	9	0.19	275	31	313.1	313.8	313.1
485.0	5959	-17.3	-43.3	8	0.17	284	40	314.6	315.3	314.6
476.2	6096	-18.0	-42.3	10	0.19	290	46	315.4	316.2	315.5
464.0	6291	-18.9	-40.9	12	0.23	288	49	316.6	317.5	316.7
449.0	6535	-21.1	-38.1	20	0.32	286	53	316.8	318.1	316.9
438.7	6706	-22.7	-40.3	19	0.26	285	56	316.9	317.9	317.0

Figure 9-7 University of Wyoming Upper Air Sounding Repository Data

http://weather.uwyo.edu/upperair/sounding.html, selection GUI left with sample output (right)

Radiosonde observations going back to 1946 are additionally available online from the National Oceanographic Atmospheric Agency (NOAA) Earth Sciences Research Laboratory (ESRL) [NOAA/ESRL] Climatic summaries of surface conditions are available for National Weather Service Stations across the country on www.weather.gov. Parameters listed in these summaries include:

- Temperature
- Precipitation
- Wind (speed and direction)
- Sky Cover
- Relative Humidity

The weather will be characterized for duration and region over which it was collected. A synopsis will be defined for each region noting typical and unusual weather phenomena that occurred during the course of the experiment in that region. Additionally atmospheric changes over the course of each given flight day will be assessed to determine the diurnal effect noting the transition time from quiescent to dynamic conditions both for the surface boundary as well as elevated changes to the atmospheric profile.

9.1.4.2 Environmental Variability

NASA has conducted Low Boom studies primarily in the vicinity of Edwards AFB, CA. The LBFD experiment will be conducted in multiple regions where the environment will differ and is not so well understood. An effort will be made to assess each of these regions for their complexity and dynamic nature prior to the LBFD flight so as to plan the best manner to monitor and characterize the environment on the day of any given flight, for example where and how often sonde measurements should be made within a region. High resolution (spatial and temporal) environmental forecasts generated through numerical weather predictions should assist in this determination. The archived data from these runs can additionally provide atmospheric profiles for subsequent PCBoom runs necessary to support the interpolation of acoustic data at a respondent's location between noise monitors.

9.2 Subjective Data Analysis

The survey instruments include single event, daily summary and baseline (background) survey questions. This set of surveys will assess annoyance due to low boom noise as well as the participants' responses on a set of features that will include aspects such as demographic variables, their attitudes towards noise in general, their attitudes towards the noise source, their individual level of noise sensitivity, and their perceived ability to habituate. Statistical tools will be developed to evaluate the responses from these subjective response assessment instruments. The processes developed will include statistical analysis to identify underlying relationships and contributing factors.

Each of the six climatic sites selected will determine the location of the communities under the flight path for that region. Noise measurements will be made in the surrounding community during the period of the survey administration. The participants will be grouped according to geographic location for correlation with the low boom noise metrics in that geographic section of the community. The statistical analysis will evaluate the subjective response variables to identify relevant factors and correlate the subjective findings with the objective noise metrics. The analysis will utilize data dependent analysis options. The methods considered will be parametric, or non-parametric, based on the data gathered. For example, if the data is skewed to the left, indicating a greater number of responses with little to no annoyance reported, then that skewed data does not support the use of linear regression. The data can be evaluated using Tau-b non-parametric categorical analysis methods assessing the strength of the dependence between the annoyance responses and contributing categorical variables such as interference, loudness, rattle or vibration. A simple Chi^2 test can assess the relationship between noise measures and annoyance by counting the data in each cell for the number of responses (across participants) in each response category for each noise level. This simple count data should be able to reveal the noise levels at which a shift in the subjective response is observed. A dose-response model will be developed if this approach is supported by the data gathered.

9.3 Subjective-Objective Data Correlation

Noise metrics can be correlated with the annoyance response data, affording the identification of measures that optimize the prediction of annoyance for a given type of noise impact. In order to analyze the data, a mixed effects linear model will be implemented using SAS® Statistical Analysis software. The analysis will include statistical estimation and analysis of the results as well as correlations of the noise metrics with the subjective responses.

9.4 Statistical Analysis

The statistical analysis will evaluate the subjective response variables to identify relevant factors and correlate the subjective findings with the objective noise metrics. The typical measure of community response to full boom noise is the percent highly annoyed within the community. However, without the use of full booms, it is conceivable that the noise exposure will not result in high annoyance in the non-acclimated community. To address this, the WSPR data analysis [Hodgdon *et.al,* 2013] implemented a range of methods for the analysis of the %HA, the daily annoyance response, and the single event response data. This was done to test and evaluate assessment procedures other than %HA in anticipation that there may not be any highly annoyed response data in the next field design. The WSPRRR analysis will utilize data dependent analysis options similar to those evaluated in WSPR. Noise measurements will be made in the surrounding community during the period of the survey administration. The methods considered for correlating subjective response data to the noise measurements will be parametric, or non-parametric, based on the data gathered. The analysis will focus on the following fundamental design concepts: Single Event Analysis, Cumulative Daily Analysis and Development of a Dose-Response Model as described below.

9.4.1 Single Event Analysis

This analysis allows for the assessment of subjective response as a function of noise level presented at different times throughout the test design. Comparisons can be made within responses from an individual participant (same person, different time, same/different levels), as well as between participants across the presentation variables (level, time of day). The single event analysis will afford a metric assessment that can be utilized in correlating human response to a single event certification metric, and to provide single event data for future consideration of community noise impact.

9.4.2 Cumulative Daily Analysis

This analysis affords the assessment of the participants rating of the overall day to correlate with the cumulative noise dose. In WSPR2011, there were issues with binning of data for the dose-response model analysis (respondents do not all hear the same noise level). It was found that different bin widths resulted in different curves and interpretation of data. This uncertainty was in some instances due to delays in the participants' response and their reporting the time at which they heard the boom was at a time in between two actual booms. We acknowledge that participants won't always respond immediately and our recommendation is that the booms be separated by at least 20 minutes to help alleviate this issue. The use of the Qualtrics survey (as described in Section 4) should also help alleviate issues as we will have the time that the survey is completed, which should help identify which boom the response is associated with.

The cumulative daily analysis assesses the current community noise impact metric, the Day Night Average Sound Level (DNL). DNL represents the accumulated noise level over 24 hours with a penalty of

10 dB given to operations taking place at night between 10pm and 7am. Comparisons can be made within responses from an individual participant as well as between participants across the presentation variables. Other cumulative metrics describing the participant daily exposure, including CDNL and PLDN will also be considered.

9.4.3 Development of a Dose-Response Model

An Exploratory Data Analysis (EDA) will be conducted prior to implementing the analysis of variance (ANOVA) or analysis of covariance (ANCOVA) model to analyze the data. The EDA approach will be used to evaluate the appropriateness of including the multiple different covariates in the analysis, because a covariate should be included only if it has a significant relationship with the response. The EDA approach will investigate which variables explain a significant portion of the variability in the response. The main predictor variables will be the characteristics of the different noise environment (due to different geographic locations). The analysis will include as many interactions as appropriate dictated by the survey response data that is obtained.

The data will determine the components of the dose-response model of the annoyance. The annoyance response will be a function of non-noise co-variables, noise effects, and random effects, as outlined below. The WSPRRR model will be of the form:

$Y = XB + B_M Met + ZA + E$, where:

Y is the *annoyance response* to be modeled, which is a function of:

Non-noise co-variables:
X is a matrix of covariates that interact with the annoyance response
B is a px1 vector of coefficients to be estimated

Noise effects:
B_M is a coefficient indicating the effect of the objective measure of noise
Met is a vector of the objective measures of noise

Random effects:
Z is an nxk matrix of random effects (e.g. community)
A is a kx1 vector of random variables
E is an nx1 vector of estimation errors

Y is the annoyance response (single events or daily summary) that is being modeled. The Baseline survey solicits information that is evaluated as potential co-variables. The single event and daily summary annoyance responses are related to noise levels. Analysis can assess responses between individuals and can also analyze responses from the same individual at different times. The predictive models can be linear or nonlinear based on the data obtained. An example of an outcome from the model is presented in Figure 9-8.

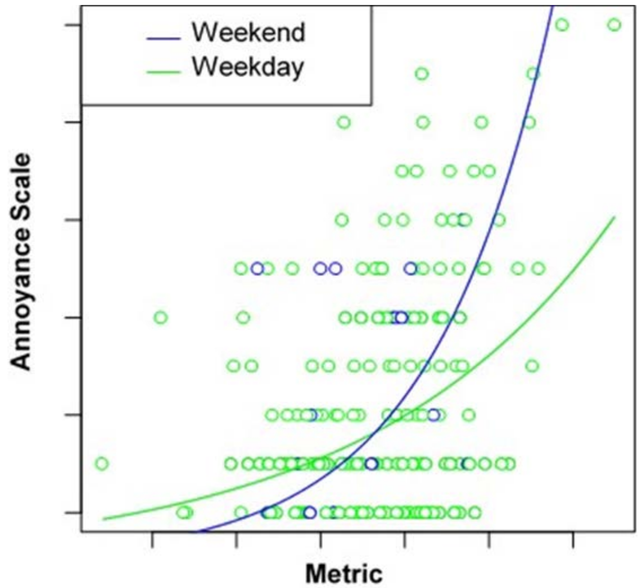


Figure 9-8 Example of Model of Predicted Annoyance

9.4.4 Review of other models

The development of our statistical design included consideration of other analysis approaches in noise research. We wanted to identify concepts that are distinct from our previous approach, but that could be applicable, and analyses that overlap and validate our approach. The "Information-criterion based selection of models for community noise annoyance" [Wilson, *et.al.* 2013] and the report on dose response relationships for overflight noise in Bryce Canyon National Park [Fleming, *et.al.* 1998] were both reviewed.

The review of ``Information-criterion based selection of models for community noise annoyance" by Wilson *et al.* [2013] did identify methods that we had not used previously but could readily incorporate into our methods. The authors concluded that random slopes models are better than models with just a random effect for community assessment. The finding is supported by the perspective that communities will perceive noise differently because of their habituation to their environment, and this should influence the relationship not only with regards to an offset (intercept), but also in the functional relationship between annoyance and loudness (slope).

We have begun to assess the applicability of random slopes models for cross-community comparisons. Prior models [Wilson, *et.al.* 2013] have used this approach with the community tolerance level (CTL, the DNL at which 50% of survey respondents are highly annoyed) and community tolerance spread (CTS, the difference between the DNL at which 90% and 10% are highly annoyed). These community-specific adjustments are typically based on a measure of % highly annoyed. Because the low booms are lower in level, we anticipate the potential to have skewed data that clusters on the less annoyed end of the rating scale. However, we propose the use of this approach as a template that can be overlaid on any annoyance response data. That is, the data does not have to be highly annoyed data to utilize this method. This may additionally address concerns regarding our method for defining %HA in that it provides an established means by which we can evaluate our response data. The factors that contribute to the annoyance response vary within each individual and across individuals, as well as within each community and across communities. A dose-response model will be developed if this approach is supported by the data gathered. We plan to implement a comparison across communities using the above methods and others; for example, a simple χ^2 test can assess the relationship between noise measures and annoyance by counting the data in each cell for the number of responses (across communities) in each response category for each noise level. If we also produce these tables of counts separately within communities, this simple count data should be able to reveal the noise levels at which a shift in the subjective response is observed across communities.

We can incorporate this method, and may find a better statistical fit for the data. However, we need to be cognizant of our objective to identify a relationship between noise metrics and annoyance response that can be applied across different communities. If we find a significant random community slope component – then we'll know from the data analysis that there are functional differences in the perception of the noise from community to community. We anticipate observing such a difference when assessing noise impact in rural vs. urban communities, since the background noise will be significantly different in those two types of communities. Our site selection is purposely including such diverse locations so that are able to gather feedback from such distinctly different communities.

The introduction of using an information criteria approach for objective model selection and the conclusion that random slopes are likely the better statistical fit for the data are both concepts of merit that warrant consideration. The cited approach taken by the U.S. Army Engineer Research and Development center [Wilson, *et. al.* 2013] utilized the Akaike information criterion (AIC) [1974] which is a measure of the quality of a statistical model compared to other models for the same set of data. Another model selection approach, the Bayesian information criterion (BIC) [Burnham, *et.al.* 2002] is based partially on the likelihood function. When applying likelihood you are given the outcome and use it to describe the function of a parameter. In contrast, with probability you are given a parameter, and use it to describe a function of the outcome. The BIC is closely related to the AIC [Burnham, *et.al.* 2002].

As applicable, we could also evaluate if these same findings hold under the use of BIC as opposed to their AIC methods. The method of Maximum Likelihood (ML) maximizes the agreement of a model with the given data set. We could also experiment with the use of Restricted Maximum Likelihood estimation, or REML. REML is a method used in fitting linear mixed models. Since AIC is known to over fit the data, and BIC is asymptotically consistent (and it seems as though their sample sizes are large), BIC might choose simpler models. REML avoids ML estimates living outside of the parameter space. It often has no impact at all, but in the rare case when the ML estimates do live near the boundary or outside of the parameter space, REML fixes the problem. In this specific example, though, given the magnitude of changes, it is unlikely that the use of REML and/or BIC would reach a different conclusion, but it would be interesting to explore.

In the report on dose response relationships in Bryce Canyon National Park by Fleming *et al.*, the data analysis models were simple logistic regressions predicting the dichotomous annoyed/not annoyed response (which was not the percent highly annoyed/not highly annoyed), which we used in WSPR. The analysis methods they employed were similar to those we have proposed. Our rural locations should provide sufficient opportunities for a quieter background that those rural findings could be used to infer the annoyance perception in the quiet environment that is typically found in national parks.

The park study used special acoustic equipment designed to measure very low-level ambient noise, because the background noise levels were rather quiet. The report emphasized the importance of including a wide range of noise doses in order to adequately assess the response, and given that their respondents were in a very quiet environment, they determined that if a participant didn’t report hearing the aircraft, they weren’t annoyed. Since background noise in our study can vary based on the participant’s activities at the time of the boom, and the relatively louder background noise in a community compared to a park, we cannot assume that a non-response is equivalent to a response of “not annoyed” if the boom were audible. In our case the perception of the boom may be masked by respondent activities or other environmental noise. For our effort, if an individual does not respond, we can tally that data as “non-response”. We are using text messages to prompt attentive listening, to keep respondents focused on the listening task.

10. Risk Identification and Mitigation Strategies

10.1 Risk Discussion – LBFD Test

As part of the LBFD experiment design process we have continually identified risks associated with the study planning, execution, and proposed data analyses associated with the experiment. We have attempted to align our process with the NASA Risk Management Handbook [NASA, 2011]. We have identified and documented individual risks in the form of risk statements with accompanying descriptive narratives for complete understanding. We have estimated the criticality of individual risks and then the aggregate risk across experiment design elements. This allows us to prioritize key risks as well as assess which design elements hold the greatest aggregate risk. Early discussions with NASA indicated that we should be mindful of safety issues associated with flight operations for the LBFD but that this was primarily a NASA area of responsibility. We have therefore focused on risks associated with the success of the experiment (attaining a legitimate measure of community response to low booms generated by LBFD overflight), and risks that have the potential of generating negative community response.

10.2 Risk Ranking

We have 33 risks in our inventory for which we've identified high level mitigation strategies. Each risk has been assigned a probability of occurrence (remaining after the proposed mitigation) as well as the consequence for each design element. The resulting impact to a given design element was calculated as the product of the probability of occurrence and the consequence. The top row of Table 10-1 reflects the distribution of total impact across design elements with the majority residing in #8 Data Analysis, #4 Survey and Dose Response, #5 Survey Implementation and Recruitment, and #7 Boom Analysis. The risks are sorted by their total impact to the experiment across all design elements, this is calculated as the sum of the impact to each design element and is reflected in the right most column.

Table 10-1 Risk Assessment

For those risks with total impact across all design elements greater than the mean

	Risk Title	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	
	Mean									24.15
	Total	63	54	80	137	121	88	108	146	
27	Participant location determination	0	0	0	16	12	8	16	16	68
25	Participant response motivation	0	0	12	12	12	0	0	12	48
26	Participant recruitment challenges	12	3	0	9	12	0	0	9	45
33	Determination of Noise at a Participant's location	0	0	0	8	0	12	12	12	44
8	Noise Monitoring across large carpet region	0	9	0	0	9	9	9	0	36
21	Cross Community Comparison	4	4	4	8	4	4	4	4	36
23	No Subjective response (Participants didn't hear it)	0	0	0	12	4	0	0	16	32
1	Transition Focused Footprint	4	5	5	2	3	3	5	3	30
2	Climb booms	4	5	5	2	3	3	5	3	30
30	Flight Trajectory Precision	6	6	2	2	2	2	6	4	30
22	low boom signature is a new noise source	0	0	4	8	12	0	0	4	28
17	Media Response	9	0	9	0	0	0	0	9	27
18	Startle or rattle	0	6	0	9	0	0	0	9	24
20	Sleep Disturbance Complexity	0	0	6	9	0	0	0	9	24
28	Low frequency building excitation	6	0	0	0	0	9	0	9	24
32	Geolocation through Qualtrics	0	0	0	0	12	0	0	12	24
24	FAA Activity Conflicts	4	2	3	4	3	0	3	3	22
13	Structural Damage not due to LB	0	0	0	4	8	0	8	0	20
14	Boom level enhancement through structural configuration	0	0	0	4	8	0	8	0	20
4	Turbulence Allowances for Noise Dose	2	0	0	4	0	6	6	0	18
5	Diurnal Affect	2	4	0	4	0	4	4	0	18
29	IRB/OMB Approval	0	0	9	0	9	0	0	0	18
31	Introduction of bias vs an informed community	0	0	9	0	0	0	0	9	18
7	Atmospheric variability	2	6	0	4	0	0	4	0	16
12	Construction Variability	0	0	0	0	8	0	8	0	16
3	Supersonic Turn focus booms	4	4	0	4	0	0	0	0	12
9	Unattended/Remote controlled noise monitors	0	0	0	0	0	12	0	0	12
11	Interior Noise	0	0	0	0	0	6	6	0	12
16	Anecdotal Influence	0	0	6	6	0	0	0	0	12
6	Turbulence detection	2	0	0	0	0	4	4	0	10
19	Night Flights - Sleep Disturbance	0	0	3	3	0	0	0	3	9
10	Noise Monitor Security	2	0	0	0	0	6	0	0	8
15	Second effect damage/injury	0	0	3	3	0	0	0	0	6

The average of the total impact for the risks across all design elements is 24.15; twelve of the 33 risks are above this average with two having the highest impact rating (16) to one or more design elements: Risk #27 Participant Location Determination and Risk #23 No Subjective Response. Figure 10-1 presents these twelve risks on a traditional Risk Cube.

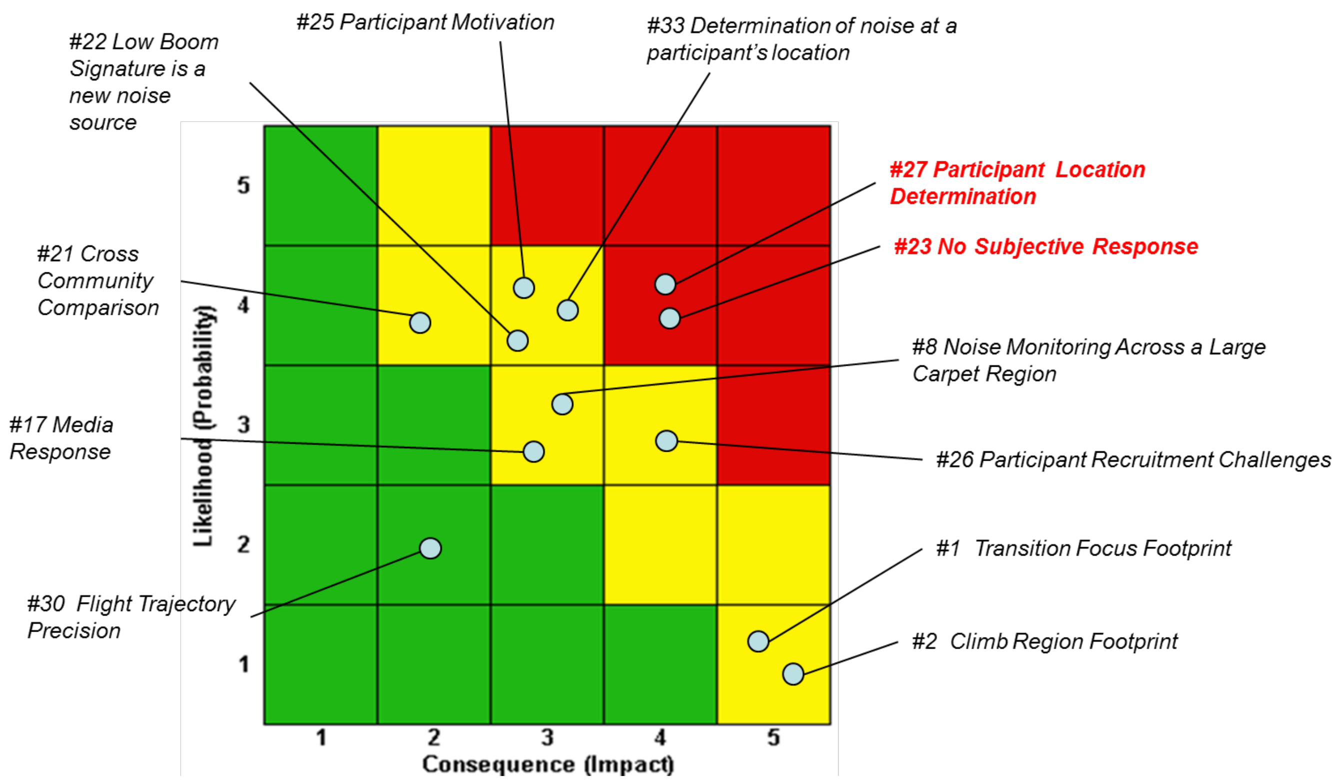


Figure 10-1 Risk Cube Assessment of Significance

For those risks with total impact across all design elements greater than the mean.

Mitigation strategies have been defined at a high level for each risk; in some cases these strategies require further exploration in Phase 2 as proposed in Section 11.

10.3 Potential Mitigation Activities

Some mitigation strategies can be explored through limited events in the laboratory or the field, for example:

- #8 Noise Monitoring Across Large Carpet Region
    - Performance of low cost noise monitors could be assessed in the Gulfstream Simulator.
    - Existing fieldkits could be enhanced to employ cellular networking and be integrated with low cost noise monitors for limited deployment along military supersonic corridors to support opportunistic remote monitoring and recording of sonic booms
- #7 Environmental Variability Assessment
    - High resolution numerical weather models could be focused on a candidate site for the LBFD experiment to support regional assessment prior to LBFD Deployment Testing as well as to assess their ability to provide atmospheric profiles that could be utilized in PCBoom
- #6 Turbulence Detection
    - SonicBAT test events could be leveraged through the deployment of low cost noise

monitors to assess their ability to detect turbulence

Further exploration of mitigation strategies associated with community or participant interaction ***require*** an event in which they can participate, for example to explore risks associated with participants' responses we must provide an event for them to respond to. A flight test which exposes a non-acclimated community to low sonic booms would satisfy this requirement. Such a flight test would provide a small scale dress rehearsal for the LBFD experiment and an opportunity to assess the mitigation strategies associated with most of the risks identified as well as valuable lessons learned. The proposed Phase 2 Flight Test does introduce unique risks which must be considered.

10.3.1 Phase 2 Flight Test Risk Drivers

There are 10 risks associated with such participant/community interaction of which eight have a total impact across all design elements greater than the average total impact for all risks.

Table 10-2 Risks Associated with Community/Participant Interaction

#	Risk Title	Impact
27	Participant Location Determination	68
25	Participant Response Motivation	48
26	Participant Recruitment Challenges	45
21	Cross Community Comparison	36
23	No Subjective Response	32
22	Low Boom Signature is a New Noise Source	28
17	Media Response	27
29	IRB/OMB Approval	18
35	Introduction of Bias vs. an informed community	18

#27 Participant Location Determination

NASA's objective is to understand the community response to sonic boom noise generated by low-boom supersonic aircraft. This requires measurement of the participant's response and quantification of the sonic boom exposure of the study participants. The LBFD experiment is envisioned to occur across a broad area over an extended period of time. Participants will not be constrained in their movements during this experiment. The participant's response must be localized both spatially and temporally so that we can interpolate the intensity of the low boom at that location based on measurements from Noise Monitors around it as described in Section 9.1.

Several methods are being explored to support localization of a participant's response, these include:

- Survey Design – questions will be defined for both the Single Event Survey and the End of Day Summary in which the participant will be requested to provide their location when they experienced each low boom.

- Use of a Qualtrics Surveys app on a GPS-enabled device - If the participant completed the survey using the Qualtrics Surveys app on a GPS-enabled device, this data will be an accurate representation of the participant's location [Qualtrics, 2015]. This approach will be subject to IRB approval and require that participants:
    1. Are informed that this data will be collected
    2. Are willing to install the Qualtrics Survey App on their Phone
    3. Respond using the Qualtrics Survey App in a timely manner to Single Event Surveys

#25 Participant Response Motivation

Test deployments of the Low Boom Flight Demonstrator will be less than 1 month in duration. During this deployment it will conduct up to three flights on any given day with each flight affording two community exposures spaced at least 20 minutes apart. The Low Boom is intended by design to be unobstrusive and study participants will be exposed to them intermittently over this extended period of time. A statistically significant number of participant responses is required to support our analytical methods. It is expected that some portion of the participants will "drop out" due to distraction and fatigue.

We must assess the effectiveness of methods to remind/motivate participants to submit their responses. Methods under consideration include:

- Email reminders for participants to complete and submit their End of Day summary
- Text messages before and/or after low boom events to prompt participants to complete and submit Single Event surveys
- Monitoring of responses to determine when more proactive techniques such as calling specific participants is necessary.

#26 Participant Recruitment Challenges

Attainment of a statistically significant number of participant responses begins with recruitment of those participants. The recruitment effort in support of WSPR 2011 spanned four months and employed multiple methods including online information, emails, letters and ultimately financial incentives ($50 VISA gift card). The end result of this effort was a pool of 171 qualified participants from which 115 were selected of which 52 were utilized in the data analysis [Page *et al.,* 2014]. Our goal is the recruitment of 1000 participants across five to six communities for each LBFD test deployment. The proposed F-18 LBDM over a non-acclimated community would be smaller in scale and therefore would have a recruitment goal of 600 participants within the region of the low boom footprint.

In Phase 2 we intend to explore the methods proposed in Recruitment Techniques Section 7.1 and provide final recommendations for those deemed most effective.

#21 Cross Community Comparison

Detailed understanding of the community response will support the development of national and international standards for civilian supersonic flight. The LBFD Experiment will be conducted across six sites comprised of different climates, topographies, and demographics. We will need to identify a method by which we can compare the response from different communities within a given region and ultimately between communities on a national level.

An F-18 LBDM can provide a footprint of sufficient size to expose multiple communities as illustrated in Figure 10-2. This would provide sufficient response data to support assessment of the methods proposed in Section 9.4.3.

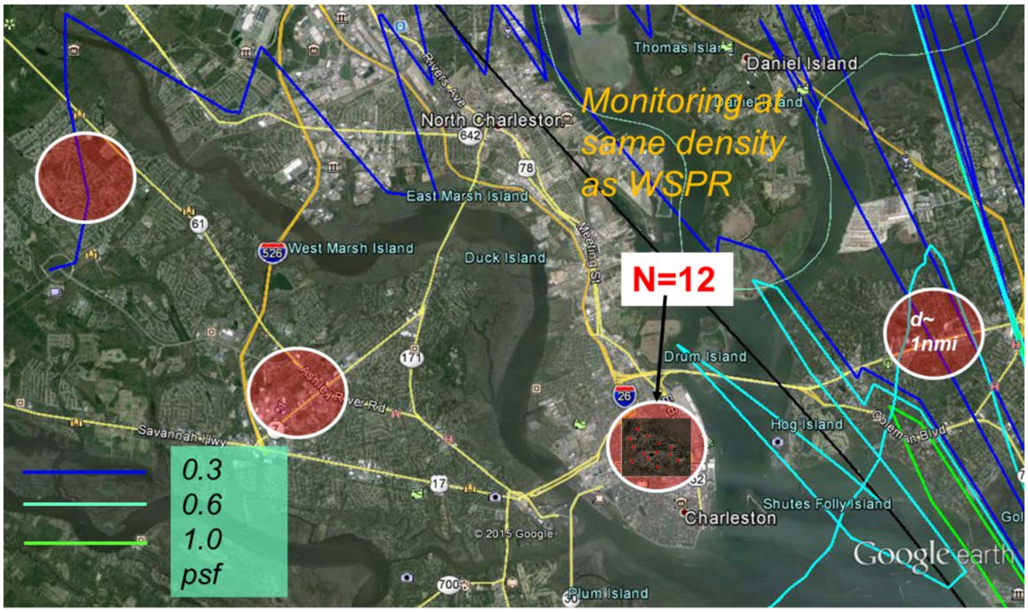


Figure 10-2 Low Boom Footprint over Charleston S.C. and surrounding areas

Generated from analysis of an F-18 Low Boom Dive Maneuver over Charleston S.C. Red circles denote approximate positions of candidate communities of the same approximate size evaluated during WSPR 2011.

#23 No Subjective Response

The low boom is designed to deliver a Perceived Level (PL) of ~75dB under the track and ~70-75 dB off track. Additionally this quiet boom will be associated with a long rise time such that it will be audible only as two low level thumps rather than the double bang of a traditional N wave sonic boom. Given these characteristics it is entirely possible that participants may not hear many of the low booms that they are exposed to. When a participant does not respond to a low boom event we must determine whether it was:

a. Legitimately not heard,
b. It was heard but not bothersome to the participant
c. The participant was distracted or beyond range of the low boom.

Methods to address this risk that will be investigated in Phase 2 include:

- Delivery of text prompts to participants immediately before LBFD flights to ensure attentive listening on their part
- Survey design to include carefully worded questions to clarify where the participant was, were

they listening, did they hear it and whether or not it was bothersome.

An assessment of no subjective response would be conducted as part of our data analysis to determine the extent to which this occurred and were we able to legitimize its cause.

#22 Low Boom Signature is a New Noise Source

Communities selected for testing with the LBFD aircraft will be unaccustomed to hearing sonic booms. Strategies must be identified that could be employed to introduce a new noise source to a community that will minimize bias in acquired annoyance data [NASA, 2015]. As discussed in Section 3.5, we plan to conduct an orientation effort using the Gulfstream Aerospace SASSII simulator to introduce respondents to the sound character of a low boom and train them on the range of low booms to be presented.

The proposed Phase 2 flight test could provide the opportunity for us to evaluate different methods for introducing the Low Boom noise source to the community. We would develop multiple introduction methods and employ them across select groups and or communities from our recruited pool of participants and follow up with a survey of these groups at the conclusion of the event. Additionally we could compare the response rate across these groups to determine the extent to which it was influenced by the method of introduction.

#17 Media Response

The digital web/social media environment allows rapid distribution of content. Some of the information distributed through the web/social media environment may be inaccurate or negative influencing the public response overall.

The proposed Phase 2 flight test could provide the opportunity to assess the community response through social media tracking tools currently under development for ASCENT. This additionally could refine outreach approaches to either minimize or respond to such content.

#29 IRB/OMB Approval

IRB/OMB approval is required to ensure the protection of human subjects participating in any experiment. The process for submitting a proposed experiment is well understood, however IRB/OMB review could place constraints upon our planned interaction with participants. These constraints could increase the complexity and expense associated with Future Community Testing with a Low-Boom Flight Demonstration Vehicle.

A Phase 2 flight test over a non-acclimated community would provide us the opportunity to submit our plan for consideration by the IRB/OMB in order to determine their priorities and the constraints that they may impose prior to the LBFD Test Deployment.

#35 Introduction of Bias vs An Informed Community

Outreach associated with the Test Deployment of the LBFD must balance “informing the community” with the introduction of bias which could invalidate the measured response. If the community is uninformed, low sonic booms could be mistaken for distant explosive events and lead to an overall negative response. If the community is well informed concerning sonic booms the analysis could be considered biased and an inaccurate measure of community response.

A Phase 2 flight test which engages multiple small communities within the low boom footprint could provide the opportunity to explore multiple outreach approaches ranging from subtle to proactive to provide valuable lessons learned for what would be most effective during the LBFD Test Deployment.

10.3.2 Additional Risks Mitigated through a Phase 2 Flight Test

A Phase 2 flight test over a non-acclimated community would additionally assist in the mitigation of the majority of remaining risks:

- Deployment of networked noise monitors on a smaller scale would be a valuable test of both the low cost noise monitors as well as the network architecture planned for their operation.
    - #8 Noise Monitoring Across Large Carpet Region
    - #9 Unattended Remote Controlled Noise Monitors
    - #10 Noise Monitor Security
- Deployment of noise monitors in an L configuration with 100 foot separation along with corresponding small commercial weather stations would provide an opportunity to assess our planned methods for the detection of turbulence and the allowances for Noise Dose required. Additionally the detection of turbulence could be correlated with changes of the atmosphere near the surface to assess the extent to which they vary through the course of a day.
    - #4 Turbulence Allowances for Noise Dose
    - #5 Diurnal Affect
    - #6 Turbulence Detection
- Instrumentation of a local government/public building could assist in assessing risks associated with the effect of low booms as perceived inside structures
    - #18 Startle or rattle
    - #14 Boom Level Enhancement Through Structural Configuration
    - #12 Construction Variability
    - #11 Interior Noise

10.3.3 Unique Risks Accompanying a Phase 2 Flight Test

A Phase 2 Flight Test over a non-acclimated community is accompanied by additional risks to which this exploration must be weighed against:

#31 F-18 Low Boom Dive Maneuver (LBDM) Signature Shape and Intensity

An F-18 LBDM is a complex maneuver with the resulting low boom being dependent upon pilot precision as well as prevailing atmospheric conditions. During WSPR 2011 it was found that the F-18 LBDM delivery of low boom overpressure was most successful for booms of ~.53 psf and attempts at lower levels, ~.33 psf and ~.13 psf typically delivered greater low boom overpressure than the target level Figure 10-3 [Page *et al.,* 2014]. The signatures associated with the LBDM are shown in Figure 10-4

[Maglieri *et al.* 2014]. Note that as the amplitudes decrease the signatures become more "rounded" like those designed into the LBFD can produce low boom shaped signatures similar to the LBFD and become more like N-waves as the amplitudes increase.

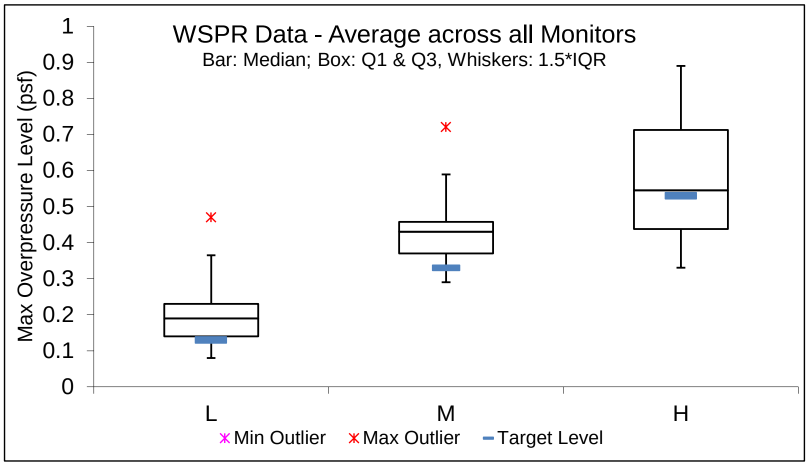


Figure 10-3 WSPR F18 Dive Low Boom Overpressure Delivery Success

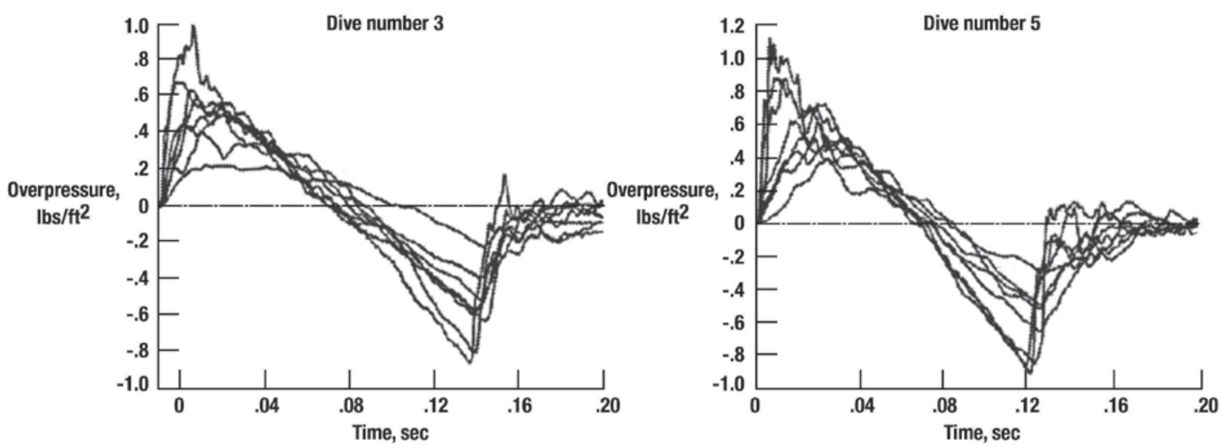


Figure 10-4 Ground-level Measurements from an F-18B in a Supersonic Low-Boom Dive Maneuver

(Image from Haering et al., 2005)

In summary, the F-18 LBDM will be a low boom but still louder and with a shorter rise time than the low boom generated by the LBFD. This could lead to inaccurate community expectations with respect to the low boom generated by a future LBFD.

In a Phase 2 Flight Test over a non-acclimated community we would need to carefully manage community perceptions and expectations with respect to future LBFD Test Deployments.

#34 F-18 LBDM Footprint Complexity

The low boom footprint is covers an area approximately 10 miles in length and 10 miles in width. This is significantly smaller than the Carpet Region associated with the LBFD Test Deployment and requires us to reorient the community selection grid relative to the footprint as seen in Figure 10-5. The grid is oriented across the footprint where overpressures are predicted to be less than 0.5psf. This differs from along the flight path as planned for the LBFD Test Deployment. The Focus Region to the right is over a body of water or uninhabited space. The smaller area available from an F-18 LBDM may not encompass entire communities and may limit our ability to engage both rural and urban environments with a single boom. The F-18 Low Boom Dive Maneuver is shown in Figure 10-6.

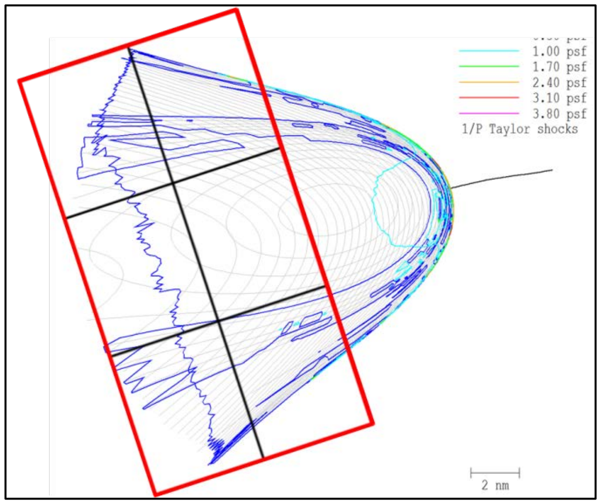


Figure 10-5 Low Boom Dive Footprint: Community Selection Grid

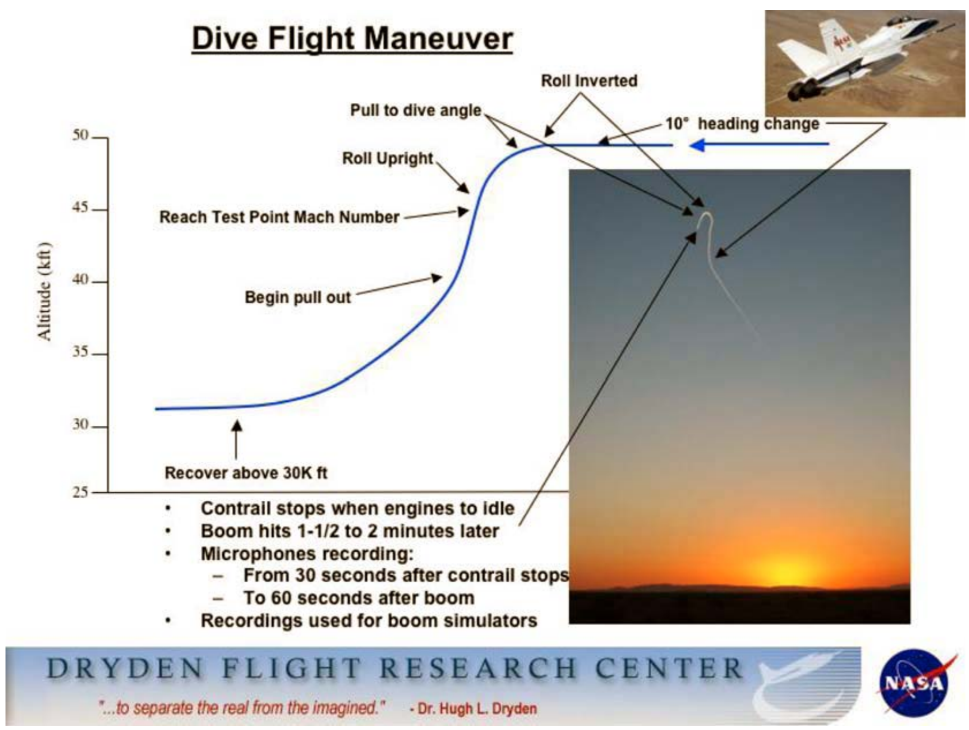


Figure 10-6 F-18 Low Boom Dive Maneuver

This maneuver results in two low boom regions as shown in Figure 10-7. The first booms to arrive are the oval shaped isopemps in the center followed by those booms indicated by crescent shaped lines.

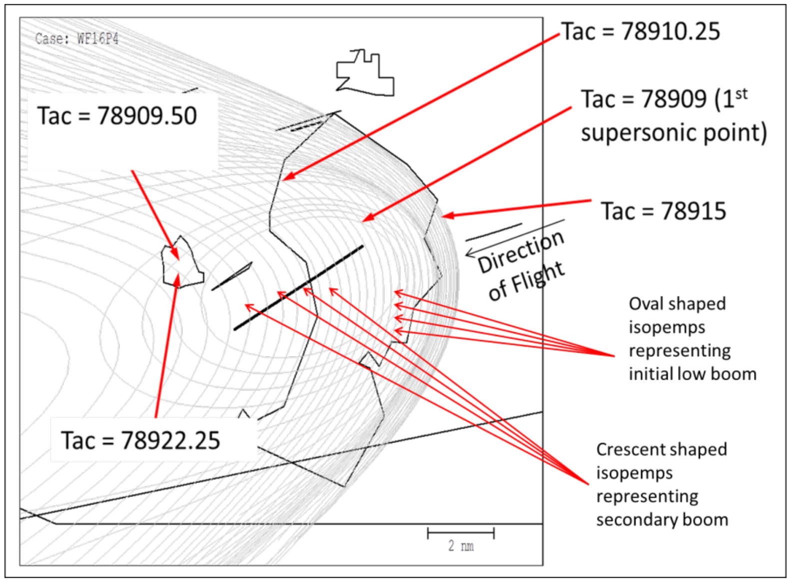


Figure 10-7 WSPR Flight 16, Pass4, Boom 65

The arrival of these booms is separated by approximately 1 second as seen in Figure 10-8.

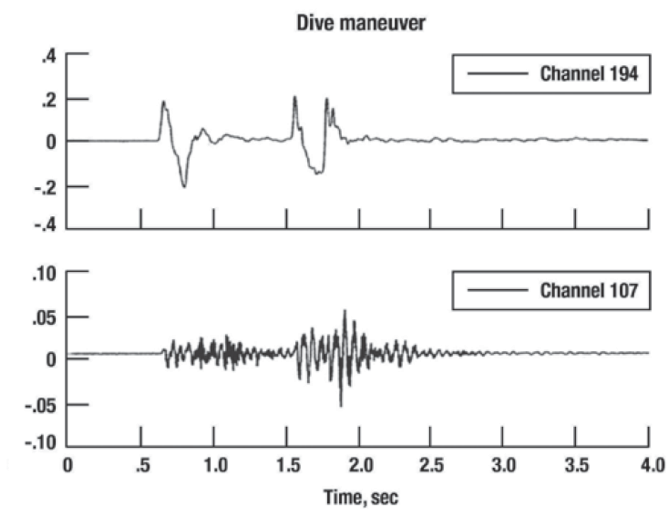


Figure 10-8 Transducer time histories: Outdoor microphone and a wall-mounted accelerometer

From a low amplitude sonic boom. Source: Klos & Buehrle, 2007.

During WSPR boom recordings were limited to 650ms so as to exclude consideration of the second boom. Further analysis with respect to exploration of atmospheric effects on booms generated through the dive maneuver as well as pilot repeatability is in order for planning the Phase 2 event. This will require collection of historical as-flown F-18 Dive trajectories from NASA as well as upper air atmospheric data for potential sites, as NASA analysis of low boom dive maneuver success rates.

The footprint of a low boom generated through an F-18 LBDM is significantly more complex than that anticipated from an LBFD. The focus boom region is much closer to the low boom region and bordered to either side by regions of higher overpressure as shown in Figure 10-7.

Site selection will be an essential element of the Phase 2 planning for a flight test. Site selection will require sufficient open space, preferably over water to accommodate the regions of higher overpressure associated with this footprint. Additionally accurate elevated measurement of the atmosphere will be a key input to the PCBoom prediction of the footprint as well as pilot proficiency in executing the low boom dive maneuver will be necessary to ensure that communities are not subjected to significant overpressures.

#32 F-18 LBDM Community Awareness

An F-18 LBDM delivers a low boom footprint forward of the dive point which would allow the maneuver to be executed offshore with delivery of a low amplitude sonic boom on a coastal community. The dive is initiated at ~50,000 feet with the aircraft rolled to an inverted attitude. When the desired dive angle is achieved the aircraft is rolled to an upright attitude and a Mach number of approximately 1.1 is achieved. At an altitude of approximately 32,000 feet a pull-up is executed to recover the aircraft at an altitude of approximately 32,000 feet [Haering *et al.,* 2005]. Such a maneuver and its resultant low boom would be considered unusual and possibly alarming to the uneducated observer on the ground, particularly if it is accompanied by contrail formation. The plan for public communications and outreach must be designed to adequately address this.

#33 F-18 LBDM Emergency Responders

NASA F-18 pilots are highly proficient and have safely executed the LBDM multiple times, additionally the maneuver would likely be executed offshore some distance from any communities. Nonetheless, there is some risk associated with it and non-acclimated communities unaccustomed to overflight by military aircraft will be highly sensitive to this.

IRB approval will require that we inform emergency responders and assist them in preparations to support the Phase 2 Flight Test. The protection of human participants is guided by ethical principles, Federal law, and institutional standards. The guiding ethical principles are embodied in the Belmont Report: Ethical Principles and Guidelines for the Protection of Human Subjects of Research. Compliance with this policy provides protections for human participants as mandated by applicable laws, regulations, and standards of local, state and Federal government agencies concerning the protection of human participants, including the U.S. Code of Federal Regulations (CFR)**:

- Title 45 CFR 46, Protection of Human Subjects, U.S. Department of Health and Human Services (DHSS), Office for Human Research Protections (OHRP)
- Title 21 CFR 50, 56, 312, 600 and 812 of the Food and Drug Administration (FDA)

The guiding principal of Beneficence requires that "persons are treated in an ethical manner not only by respecting their decisions and protecting them from harm, but also by making efforts to secure their well-being.

** Policy RP03 The Use of Human Participants in Research

We need to inform emergency responders as they will most likely get a call if there are any damages. It was stated at the WSPRRR Kick-Off meeting that damage liability would fall back to NASA since they are flying the plane. If an emergency should occur NASA should lead the public relations after such an incident. Community members need to be able to be referred to a specific NASA point of contact identified in advance. Emergency responders include not only community police and fire departments but additionally community points of contact that would field complaints or inquiries. Aviation noise complaints are typically made to the Airport Noise Manager. The local airport noise manager is also a valuable resource in terms of knowing their community, so we should include them for that reason.

#12 Construction Variability & #14 Boom Level Enhancement through Structural Configuration

We investigated building response to Sonic Booms and noted that high rise buildings and particularly V shaped buildings (where the shock wave enters the open part of the V) can be susceptible to enhancement of the sonic boom and possibly some minor damage. Given that the LBFD is anticipated to deliver a .3 psf boom the possibility of damage is considered minimal, however the low boom delivered from an F-18 LBDM may result in higher Δp. Figure 10-9 presents typical high rise beach front construction that can be found in coastal communities such as Panama City Florida.

Figure 10-9 High Rise construction along the Panama City Coastline

A key mitigation strategy for this will be through the identification of these structures as part of our Phase 2 Site Selection Process as detailed in section 11.4.1. Such structures may require additional outreach efforts, pre-test surveys, and noise monitoring during the F-18 dive flight test. One of the items to be considered in Phase 2 is the incoming sonic boom propagation ray angles relative to the high rise buildings. The F18 dive maneuver results in long propagation distances at low angles relative to the ground whereas the LBFD overflights will have larger incoming ray path angles.

11. Phase 2 Activities Proposal

As noted in section 1.1, non-acclimated communities present additional challenges beyond those overcome during the WSPR experiment. These include: the absence of a predisposition to aircraft noise; willingness to participate in the experiment; safety and security, and a host of other issues that present risks to the success of the experiment and the attainment of certification for supersonic overland flight. This is reflected in Section 10.3.1, where eight of the twelve most significant risks involve community/participant interaction. Further exploration of these risks and the strategies for their mitigation necessitates an event that engages both communities and participants. Such an event would additionally allow exploration of lesser risks as identified in Section 10.3.2.

In the absence of the LBFD it is proposed that an F-18 executing a Low Boom Dive Maneuver be used to generate the stimulus to which the community response will be measured and assessed. This will necessarily introduce unique risks as described Section 10.3.3.

Our Phase 2 proposal begins with those early activities necessary to address these risks as well as those risks that can be explored on a more limited scale; leading to a successful Phase 2 community response test that would ultimately contribute to a successful LBFD community response test.

11.1 Phase 2 Efforts Related to Objective Noise Measurements

A Phase 2 objective would be the demonstration of noise monitoring across a wide area through unattended sensors . Risks on which we will focus include:

- #6 Atmospheric Turbulence Detection
- #8 Noise Monitoring Across a Large Carpet Region
- #8 Unattended/Remote Controlled Noise Monitors
- #10 Noise Monitor Security

The Phase 2 efforts associated with these objectives are presented in Figure 11-1.

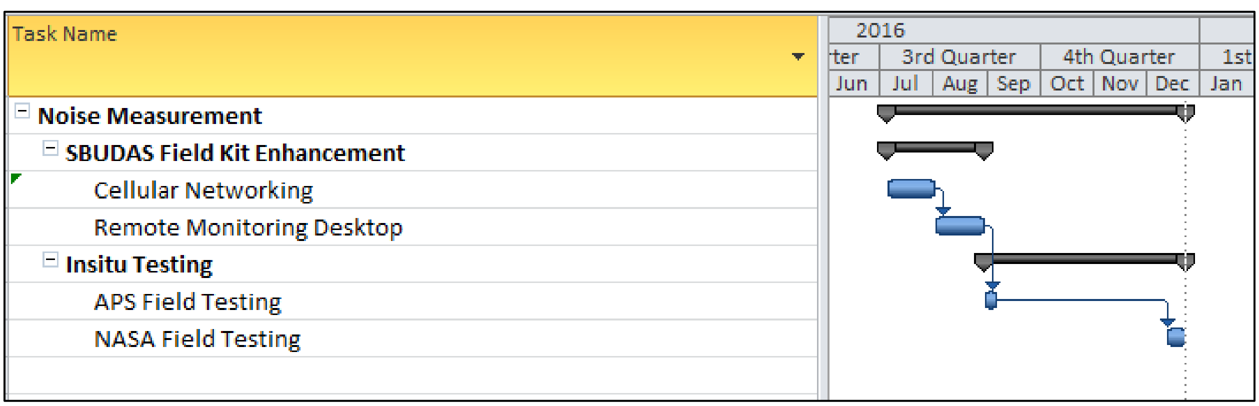


Figure 11-1Early Phase 2 efforts related to objective noise measurements

Noise measurements in a Phase 2 event would rely on the 12 existing SBUDAS Field Kits described in section 6.1.1.

A determination will be made in Phase 2 regarding the measurement of vibration at a typical dwelling type for a representative location at each site. The expectation is that the vibration data would demonstrate the outdoor noise impact was associated with minimal structural vibration impact. This determination is partially dependent on the distribution of the noise impact laterally across the carpet, which is a yet to be determined final characteristics of the LBFD vehicle.

This collection of 12 SBUDAS Field Kits would be integrated through cellular networking with a single base station computer for system control and data archival and analysis. Cellular networking connects each of these components to the internet where they connect with each other over a virtual private network (VPN). This would support initial testing at distributed geographic sites, e.g. the base station with SBUDAS Field Kits at Gulfstream Aerospace in Savannah Georgia. A subset of these noise monitors could be deployed at the Armstrong Flight Research Center for testing with sonic booms of opportunity from Edwards Air Force Base (EAFB) or in conjunction with scheduled SonicBAT flight tests if feasible.

Ultimately these 12 sensors would be distributed across the non-acclimated communities selected for the Phase 2 test.

11.2 Phase 2 Meteorological Efforts

Our Phase 2 meteorological efforts will require assessing the availability and quality of historical/climatological data to support planning as well as the availability of insitu data to support analysis of the Phase 2 data collected as shown in Figure 11-4.

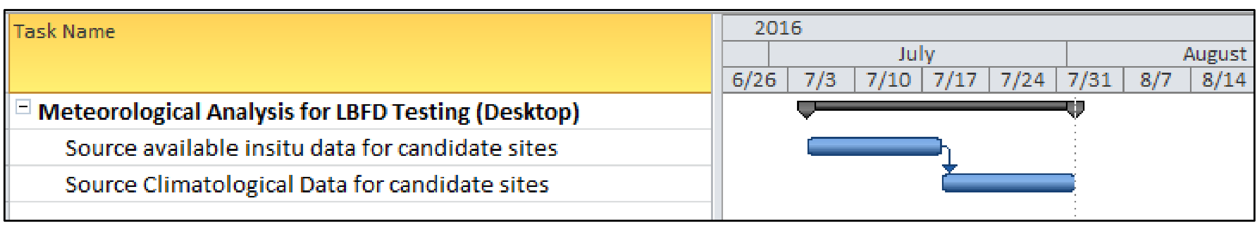


Figure 11-2 Phase 2 Meteorological Efforts

11.3 F-18 Low Boom Dive Dose-Response Test

WSPR 2011, which key members of our team both designed and participated, was envisioned as a first step towards conducting a community response test over a “non-acclimated community.” It is proposed that Phase 2 of this effort conducts this test. Design and execution of the Phase 2 Community Response Test will exercise all of the processes described in this Conceptual Test Plan allowing for their refinement and the collection of lessons learned that will ultimately contribute to a successful community response test of the Low Boom Flight Demonstrator.

A Phase 2 test over a non-acclimated community presents unique risks concerning recruitment, communications and outreach, and interaction with participants through subjective surveys as discussed in Section 10.3.1. This event will employ the results of all the Phase 2 activities. High level milestones for this event are presented in Figure 11-6.

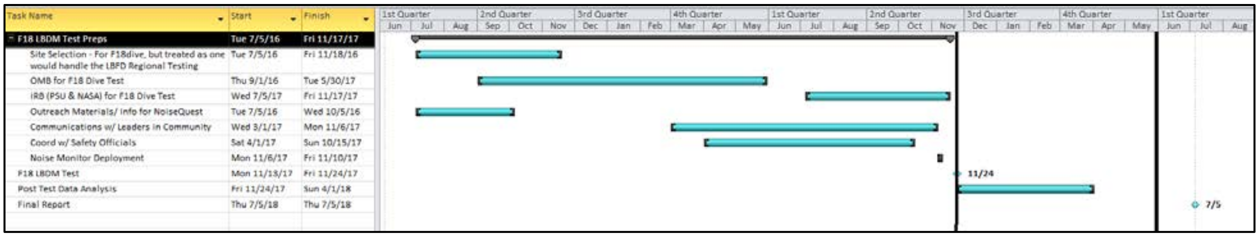


Figure 11-3 F-18 Low Boom Dive Dose Response Test Milestones

11.3.1 Candidate Site Selection

The process for selecting bases of operation for the proposed F/A-18 dive test is similar to the procedure for the LBFD test, but generally on a smaller scale. Aspects of the site selection process that remain the same include preference to government owned installations, airports with runways greater than 9,000 ft., and proximity to large bodies of water. The bases of operation chosen for the LBFD test will be given top priority in the selection procedure for the F/A-18 dive test. Using the same base of operation for both tests will allow the team to build useful relationships with the operations teams at those sites and also with the surrounding communities (outreach, education, etc.). Despite attempting to use the same bases of operation, it must be a higher priority to avoid any sort of acclimation in the candidate communities already selected for the LBFD test. Different exposure areas and communities will be chosen to the F/A-18 dive test to ensure that the participants of the LBFD test are not influenced by the F/A-18 dive test.

The total number of recruits needed from a single site for the F/A-18 dive test is 500, compared to the 1000 required for the LBFD test. To accommodate the smaller recruiting sample size, the total number of “grid cells” in which to target recruits is decreased from 12 to 6. The total size of the recruiting area is based on the approximate size of the anticipated area of the boom within the appropriate pressure levels (0 - 0.5 psf) produced by the F/A-18 dive maneuver, as modeled in PCBoom. A sample footprint and grid placement is shown below in Figure 11-7. It is likely that the grid cell areas will be reduced in size to account for variations in the F-18 Dive footprint. The conceptual layout presented in the report is reflective of a nominal dive in a quiescent atmosphere. The grid cells outline potential prominent communities from which demographics and community parameter and then ABS regions can be identified. When Phase 2 commences, detailed site selection will include an assessment of weather effects on the F-18 dive footprints during the projected test period. The grid concept will be used in Phase 2 so that it is as close a representation to the future QueSST design as possible, however the grid size will likely be adapted to better match the Phase 2 testing site. Additionally, the communities will be instrumented for the Phase 2 test so the delivered dose will be measured directly in at least one location for each prominent community. The instrumentation layout will be optimized to minimize the reliance on PCBoom for determination of the delivered low-boom dose. In the regions near cut-off the signature is often distorted. This will also be true for the future demonstrator. In order to get a proper representation of the full carpet dose-response one should not deliberately avoid testing near cut-off.

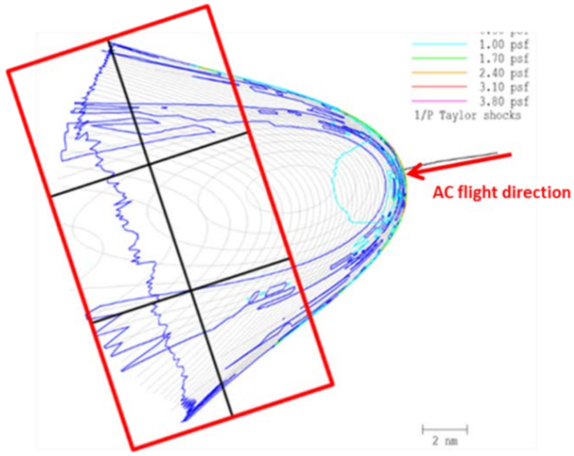


Figure 11-4 F/A-18 Low Boom Dive Maneuver Footprint and Associated Grid Cell Placement

The shape of the boom footprint is variable and will change in response to atmospheric conditions (wind speed, direction, and temperature). The size of the grid presented in Figure 11-7 is approximately 20 n.mi. by 8 n.mi.

The general expected shape of the footprint from the low-boom dive maneuver limits the geographical placement due to the focus boom concentrated in the “arc” on the right side of Figure 11-7. This focus boom contains levels well above 1 psf, and therefore should not be placed over land, especially over populated areas. To avoid this, sites selected must accommodate the placement of the focus over a body of water. Combined with avoiding proposed LBFD study areas, this placement requirement eliminates a few proposed LBFD sites and bases of operation because they are not in close enough proximity to a large body of water or do not have a sufficient surrounding population that is not already proposed for study in the LBFD testing. These LBFD sites excluded from consideration include Wheeler-Sack AFB (Upstate NY, Cold Region), Joint Base Lewis-McChord (Seattle, WA, Marine Region), and General Mitchell Int’l Airport (Wisconsin, Cold Region).

Another important consideration for site selection is the stability of meteorological and atmospheric conditions during the time period when we anticipate to perform the tests, most likely in the late winter/early spring (January - March). For this reason, more southern sites were selected as potential bases of operation because they will most likely have weather and atmospheric conditions favorable to the F/A-18 dive maneuver and data collection. In total, there are currently four viable bases of operation under consideration for the F/A-18 dive tests for Phase 2, listed in Table 11-1.

Potential F-18 Low Boom Dive Test Site Base of Operations

Table 11-1 Potential F-18 Low Boom Dive Test Site Base of Operations

Base of Operation	Recruitment Location	Climate Region
Ellington Field JRB	Galveston, Texas	Hot-Humid
Otis ANG Base	Cape Cod, Massachusetts	Cold
Shuttle Landing Facility	Titusville, Florida	Hot-Humid
Eglin AFB	Valparaiso, Florida	Hot-Humid

Daily historical meteorological and atmospheric data can be found for all of the selected sites, and will be leveraged in PCBoom to create more accurate boom contours specific to those regions in order to make better decisions regarding boom and grid cell placement in Phase 2 (See Appendix B).

An overview of the Galveston Texas testing area and boom placement concept is identified in Figure 11-8. In Figure 11-9 is an F-18 Low boom dive overpressure contour and recruiting grid overlaid on the Galveston, TX area, with flight operations based out of Ellington Field JRB in Houston, TX. Figure 11-11 demonstrates the division of recruits and recruiting targets between the six grid cells based on their location in Figure 11-9 while the population density is depicted in Figure 11-10.

Corresponding graphics for the other three potential F-18 LBDM test sites follow in Figure 11-12 to Figure 11-23.

Ellington Field JRB – Houston, TX

- Focus placement – Gulf of Mexico
- Potential Communities
  - La Marque
  - Galveston
  - Texas City
  - Hitchcock
- Annual surface weather conditions
  - https://weatherspark.com/averages/30381/Galveston-Texas-United-States

Figure 11-5 Ellington Field JRB, Houston Texas and Galveston Texas Potential Recruitment Area

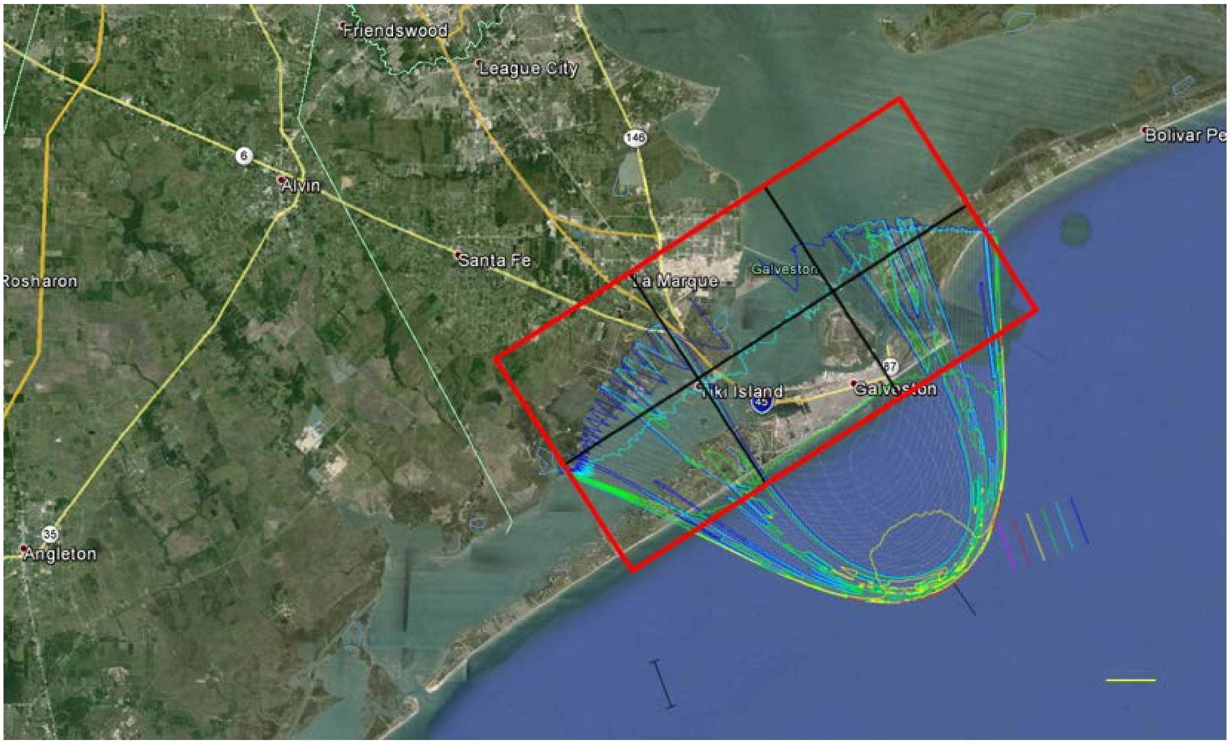


Figure 11-6 Boom Footprint and Grid Cell Placement over Galveston, TX

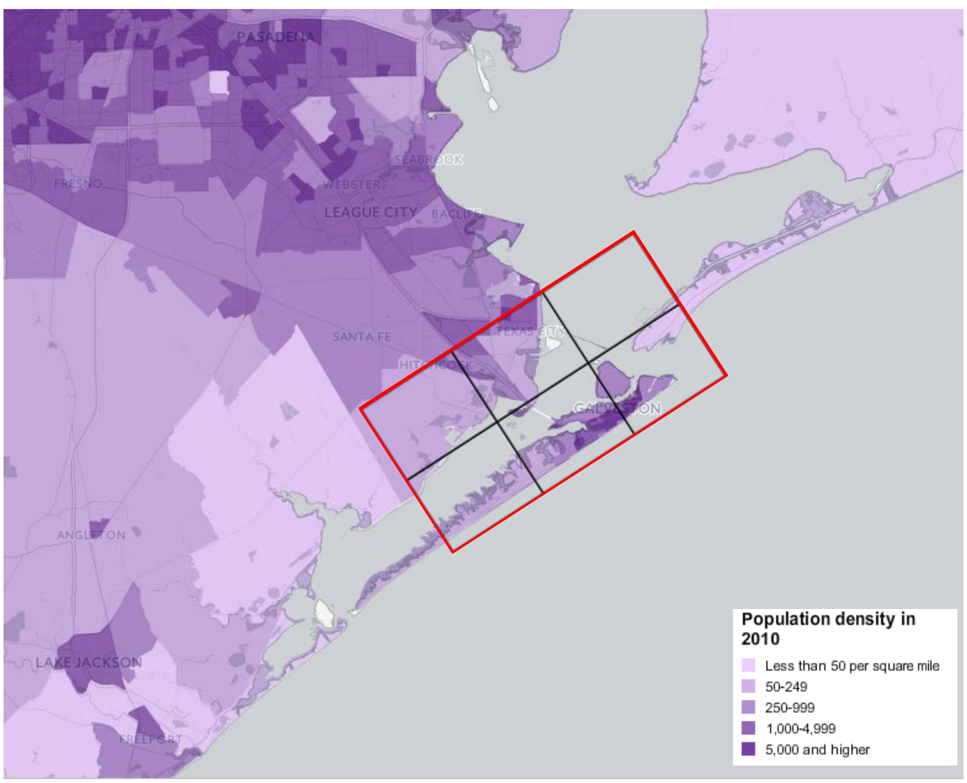


Figure 11-7 Population Density in the Galveston Area

2010 Population

Hitchcock 7,000	Texas City 45,000	n/a
Jamaica Beach 1,000	Galveston 48,000	Bolivar Peninsula 2,500

Percent of Total Population

Hitchcock 6.16	Texas City 43.48	n/a
Jamaica Beach 1	Galveston 46.38	Bolivar Peninsula 2.42

Recruits per Community

Hitchcock 34	Texas City 217	n/a
Jamaica Beach 5	Galveston 232	Bolivar Peninsula 12

Targets Required

Hitchcock 152	Texas City 978	n/a
Jamaica Beach 22	Galveston 1043	Bolivar Peninsula 54

Figure 11-8 Population, Recruiting, and Targeting in Galveston area

Otis ANG Base – Falmouth, MA

- Focus placement – Atlantic Ocean
- Potential communities
  - Falmouth
  - Barnstable
  - Mashpee
  - Bourne

- Annual surface weather conditions
  - https://weatherspark.com/averages/30282/Falmouth-Massachusetts-United-States

Figure 11-9 Otis ANG Base, Falmouth Massachusetts Potential Recruitment Area

Figure 11-10 Boom Footprint and Grid Cell Placement over Cape Code, MA

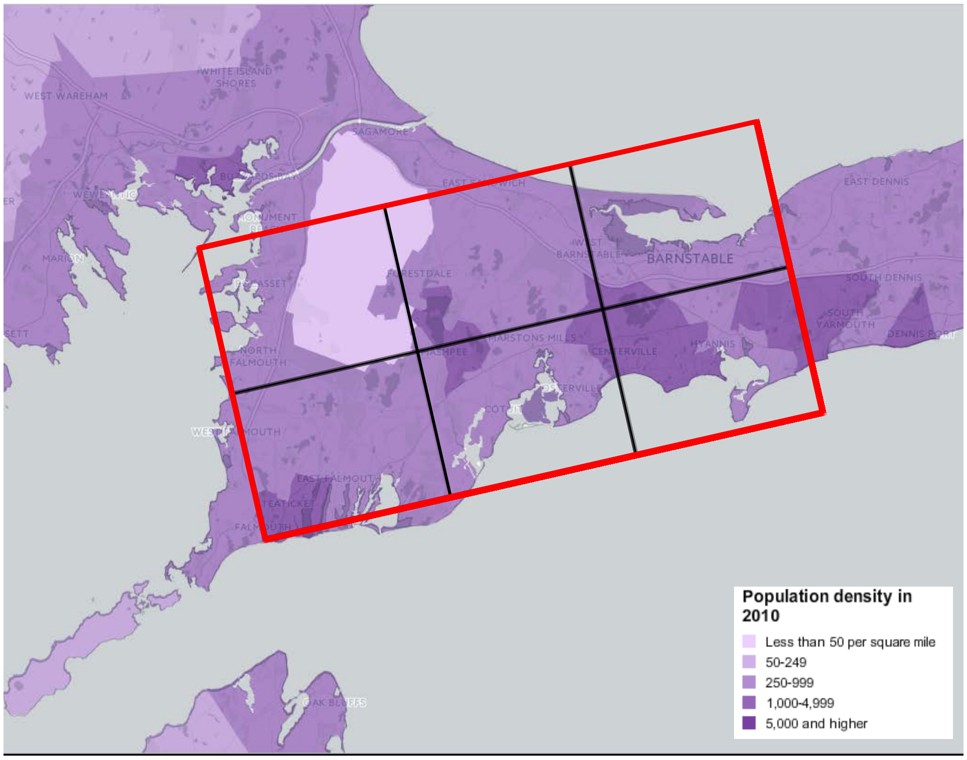


Figure 11-11 Population Density in the Cape Cod Massachusetts Area

2010 Population

Bourne 20,000	Sandwich 21,000	N. Barnstable 22,500
Falmouth 31,500	Mashpee 14,000	S. Barnstable 22,500

Percent of Total Population

Bourne 15.21	Sandwich 15.97	N. Barnstable 17.11
Falmouth 23.95	Mashpee 10.65	S. Barnstable 17.11

Recruits per Community

Bourne 76	Sandwich 80	N. Barnstable 86
Falmouth 120	Mashpee 53	S. Barnstable 86

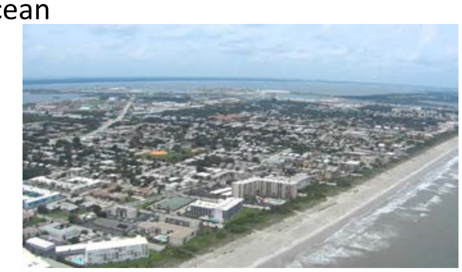
Targets Required

Bourne 342	Sandwich 359	N. Barnstable 385
Falmouth 539	Mashpee 240	S. Barnstable 385

Figure 11-12 Population, Recruiting, and Targeting in Cape Code, Massachusetts

Shuttle Landing Facility – Titusville, FL

- Focus placement – Atlantic Ocean
- Potential Communities
  - Satellite Beach
  - Cocoa
  - Rockledge
  - Melbourne
  - Port Canaveral



- Annual surface weather conditions
  - https://weatherspark.com/averages/31967/Cocoa-Beach-Florida-United-States

Figure 11-13 Shuttle Landing Facility, Titusville Florida and Potential Recruitment Area

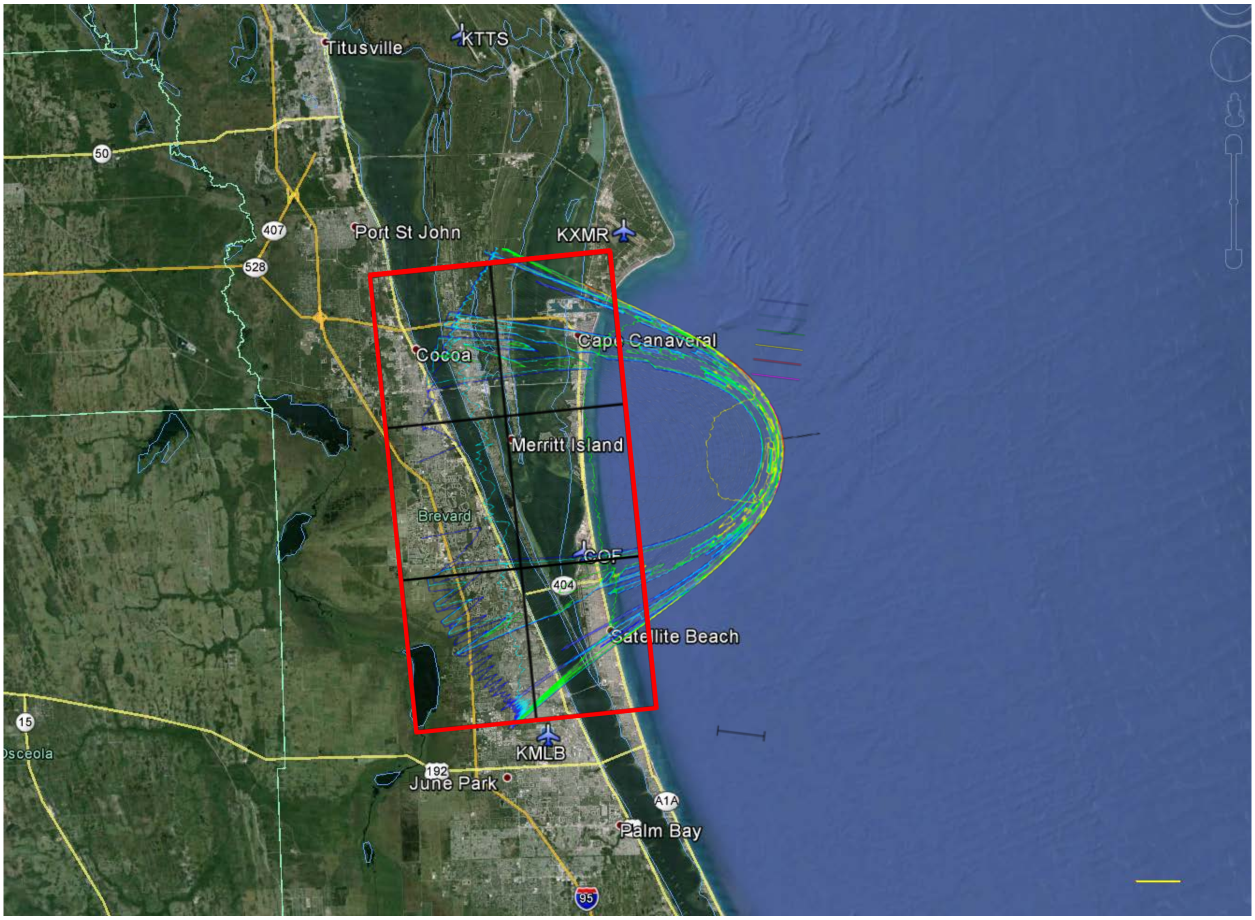


Figure 11-14 Boom Footprint and Grid Cell Placement over Titusville, Florida

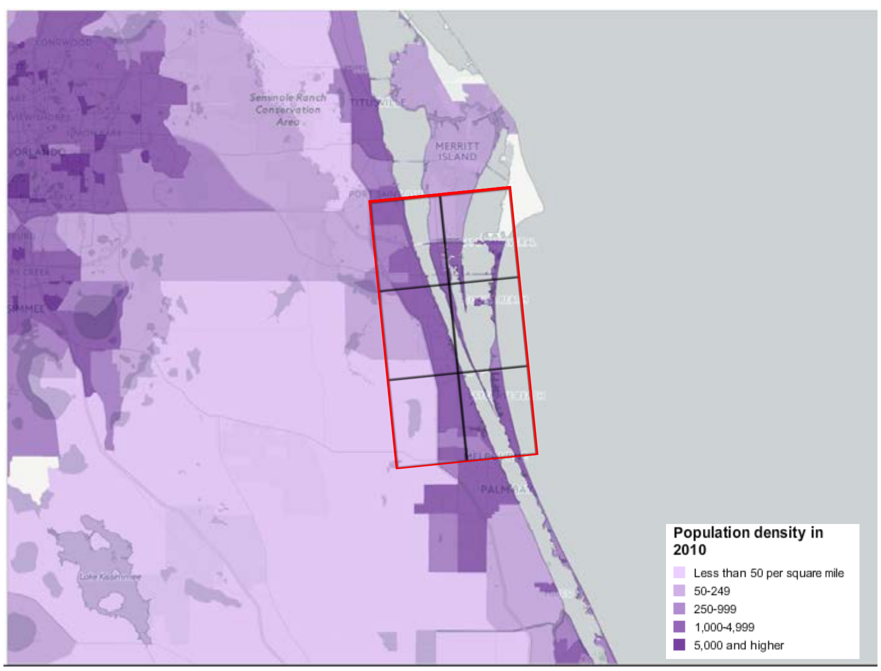


Figure 11-15 Population Density in the Titusville, Florida area

2010 Population

Cape Canaveral 10,000	Cocoa Beach 11,000	Satellite Beach 10,000
Cocoa 17,000	Rockledge 25,000	N. Melbourne 76,000

Percent of Total Population

Cape Canaveral 6.71	Cocoa Beach 7.38	Satellite Beach 6.71
Cocoa 11.41	Rockledge 16.78	N. Melbourne 51.01

Recruits per Community

Cape Canaveral 34	Cocoa Beach 37	Satellite Beach 34
Cocoa 57	Rockledge 84	N. Melbourne 255

Targets Required

Cape Canaveral 151	Cocoa Beach 166	Satellite Beach 151
Cocoa 257	Rockledge 378	N. Melbourne 1148

Figure 11-16 Population, Recruiting, and Targeting in Titusville, Florida area

Eglin AFB - Valparaiso, FL

- Focus placement – Gulf of Mexico
- Potential Communities
  - Fort Walton Beach
  - Destin
  - Wright
  - Valparaiso

- Annual surface weather conditions
  - https://weatherspark.com/averages/31900/Valparaiso-Florida-United-States

Figure 11-17 Eglin Air Force Base, Valparaiso Florida Potential Recruitment Area

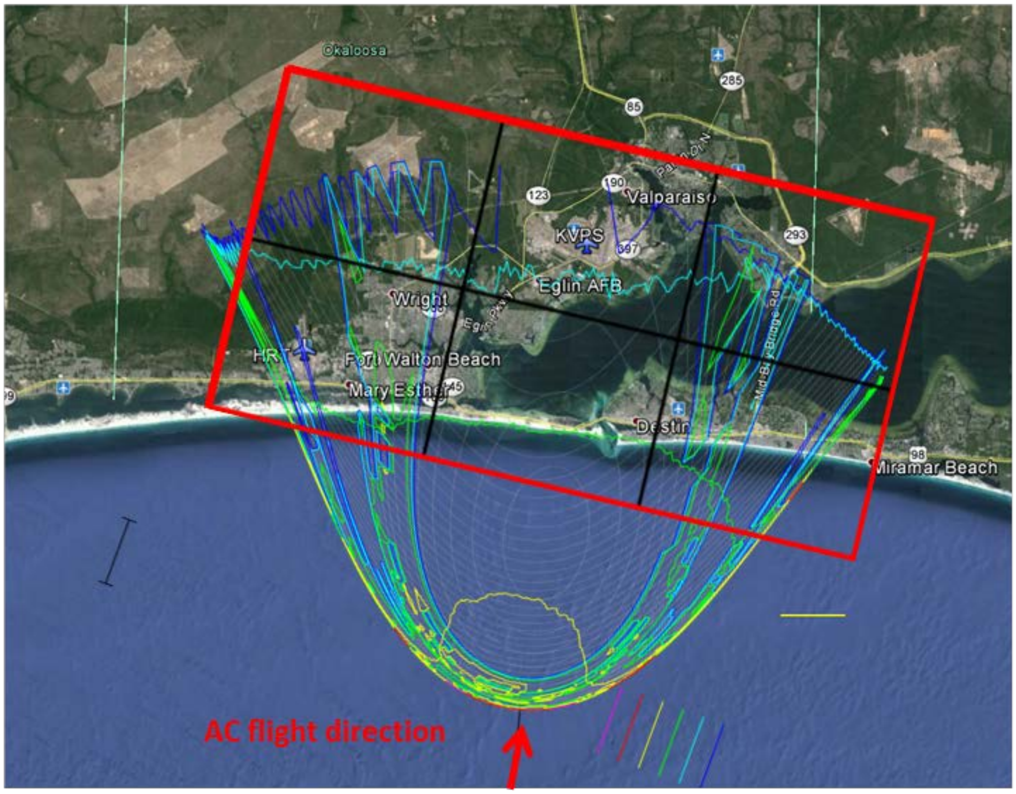


Figure 11-18 Boom Footprint and Grid Cell Placement in the Valparaiso Florida Area

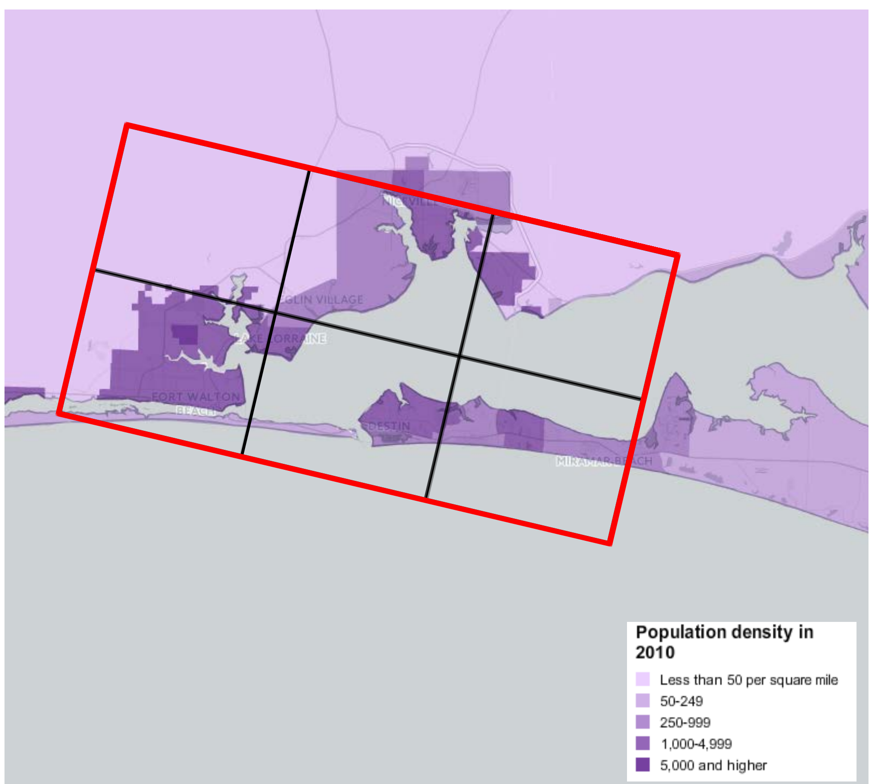


Figure 11-19 Population Density in the Galveston Area

2010 Population

n/a	Valparaiso 5,000	Niceville 13,000
Fort Walton Beach 19,500	Destin 12,000	Miramar 6,000

Percent of Total Population

n/a	Valparaiso 9.01	Niceville 23.42
Fort Walton Beach 35.14	Destin 21.62	Miramar 10.81

Recruits per Community

n/a	Valparaiso 45	Niceville 117
Fort Walton Beach 176	Destin 108	Miramar 54

Targets Required

n/a	Valparaiso 203	Niceville 527
Fort Walton Beach 791	Destin 486	Miramar 243

Figure 11-20 Population, Recruiting, and Targeting in Galveston area

11.3.2 Survey Instruments and Implementation

Objectives for Phase 2 with respect to survey instruments and their implementation include:

- Finalize survey instruments
- Implement web based data collection for the input of noise survey data from respondents
- Implement text prompts to promote “attentive listening”
- Assess the GPS location aspect of the Qualtrics software (leveraged with ASCENT through SRC)
- Explore the use of social media as a means to monitor community response (ASCENT with SRC)

In Phase 2 the subjective test instruments and assessment methods will be finalized. The survey instruments will be based on the existing WSPR surveys.

11.3.3 Formulate and Submit Compliance Protocols

Objectives for Phase 2 with respect to compliance protocols include:

- Develop and submit IRB protocol to PSU IRB
- Submit protocol and outcome of IRB review to NASA IRB
- Coordinate approvals between PSU and NASA IRB
- Develop OMB submission package
- Submit OMB package to NASA entities for final submission to OMB

The team will develop protocol submissions for compliance with IRB and OMB regulations. We will prepare and submit an application to its Institutional Review Board (IRB) for use of human participants in the experiment. The team will submit the relevant IRB information and the feedback from the IRB meeting concerning the evaluation of the research design. The PSU IRB adheres to 45 CFR 46, or the Common Rule, for the Protection of Human Subjects via a federal wide assurance with the federal government. NASA adheres to 45 CFR 46, under 14 CFR 1230, which is the Common Rule CFR number designated to NASA. Because both PSU and NASA adhere to the Common Rule, both institutions are following the same federal regulations. If NASA determines that the research field test must be referred to the LaRC IRB for review and approval, we will work with the NASA LaRC IRB office to conduct a joint IRB review with both IRB offices. We will work in coordination with the NASA Technical Representative, to prepare the information necessary for an application to OMB under the Paperwork Reduction Act. The OMB form 83-I and associated Supporting Statement will be drafted and submitted to OMB.

11.3.4 Recruitment

Phase 2 Recruitment Objectives include:

- Coordinate community selection with site selection criteria
- Execute recruitment from the selected community for noise survey participation

The site selection criteria will be used to identify the communities that will be targeted for recruitment. The distribution of recruits across targeted communities is detailed under the Site Selection process. The recruitment will be conducted in the same manner as planned for the LBFD Community Response Test, the difference being that they would be on a smaller scale and focused on the communities identified in the area of the Phase 2 Test.

11.3.5 Community Engagement and Outreach

Phase 2 objectives for community engagement and outreach include:

- Finalize community specific engagement plan
- Identify community specific local government officials and community leaders
- Identify language and format for initial community engagement and press releases
- Design and create outreach materials
- Identify the appropriate NASA representatives to team with for Outreach
- Conduct community engagement with leaders
- Conduct familiarization with participants using Simulator Days
- Coordinate with NASA to promptly conduct media release if issues are observed on social media
- Implement strategies for positive Outreach after field test

Community engagement and outreach are critical for the success of the field test. Community engagement and Outreach will be conducted in the same manner as planned for the LBFD Community Response Test, the difference being that they would be on a smaller scale and focused on the communities identified in the area of the Phase 2 Test. Within Phase 2, we will follow the strategies previously outlined. The strategies for positive community engagement will be finalized and implemented in the test community. This will include community specific identification of local government and community leaders, and a strategy for engagement. Materials for community engagement and outreach will be developed and created. Press releases will be developed to afford a quick release to media outlets in the event that social media monitoring observes community concern related to the conduct of the test.

11.3.6 Survey Execution

Phase 2 survey execution objectives include:

- Gather subjective response data
- Observe social media

The survey will be implemented in a web based format. The implementation of the social media monitoring tools will be conducted by leveraging ASCENT resources and working with the Survey Research Center. Implementation of social media monitoring for the test will be conducted as part of the NASA supported survey effort at the Survey Research Center. The survey data will be gathered from respondents in the participating community and the data compiled for statistical analysis.

11.3.7 Noise Dose Plan and Field Coordination

Phase 2 objectives for Noise Dose Plan and Field Coordination include:

- Determine noise dose plan
- Coordinate field noise dose as warranted during the field test with NASA
- Actual flight days and subsequent daily noise dose will be dependent on flight go/no-go conditions

The team will finalize the field design for presentation and assessment of noise impact. Careful flight planning will direct an intended noise dose over the communities in which we have recruited respondents and located noise monitors. We will provide input to the overflight test plan as it relates to the noise dose over the identified communities. The key here is to note that actual noise dose will differ from planned dose, so closely coordinated test day plans will be adjusted as required with NASA flight operations. This will be a team effort. The actual flight days and subsequent daily noise dose will be dependent on flight go/no-go conditions. As such, the actual field dose may vary from the noise dose plan due to flight conditions.

The anticipated noise dose varies as a function of location under the flight path. For future LBFD testing the noise impact directly under the track is anticipated at approximately 75 PLdB, with off-track levels anticipated at approximately 70-75 PLdB. In off design conditions it may be possible to present a level as high as 85 PLdB. For the F-18 LBDM test, the noise dose will identify single-event levels, number of booms per day, times of day, and number of test days for the sonic boom exposure. The test has been designed to evaluate both single event and daily cumulative levels. This noise dose design should provide sufficient data to establish a relationship between cumulative event levels and a single event level suitable for incorporation into a noise regulation.

It is likely that the low boom level will not elicit a large number of responses in the defined range for % Highly Annoyed. As such, we do not anticipated that the low booms will have a highly notable impact on the test community. However, the first few days of the noise dose will have lower cumulative daily doses, either due to level, or number of booms, to afford an introduction of the noise to the community. Previous research has shown that the net effect of habituation and sensitization is dependent on the interaction between stimulus level and number of stimuli [Petrinovich, 1984]. That is, the level and number of booms per day may affect the ability of a community to acclimate to the noise. This is in keeping with anecdotal recommendations that a new noise source should be introduced gradually to communities in order to afford the community the opportunity to adjust and acclimate to the noise. As such, we will plan a short introductory period and days with the highest number of booms will be presented as the noise dose on a day that occurs later in the field test.

11.3.8 Assessment of Analysis Methods

Phase 2 objectives for the assessment of analysis methods include:

- Update subjective test design based on most current findings to enhance ability to assess annoyance
- Conduct statistical correlations and analysis
- Provide insights into the interpretation of the findings

11.3.9 Objective Measurements

The methods described in Section 6 will be applied for the collection of Noise Measurements for correlation with the Subjective Response across the non-acclimated community. The primary difference with the LBFD Conceptual Test Design is that the area used for F-18 LBDM will be much smaller. This will involve the deployment of the network of 12 SBUDAS Field Kits, across the communities within the F-18 low boom footprint. As described in Section 6.1.4, this network of sensors will be connected to a single base station which would be setup at the WSPRRR base of operations in the vicinity of the non-acclimated community.

Rawinsonde data would be collected by NASA as required by the F-18 Low Boom Dive Maneuver protocol. This data as well as surface observations will be made available for planning purposes as well as archived for posttest analysis. If COAMPS OS support is approved it will be utilized over the test community as described in Section 12.

11.3.10 Boom Analysis

The F-18 LBDM will produce a low altitude boom that will serve as a surrogate for the low boom delivered by the LBFD; as such it will be subject to the unique risks accompanying a Phase 2 flight test as described in Section 10.3.3, in particular:

- #31 F-18 Low Boom Dive Maneuver (LBDM) Signature Shape and Intensity
- #34 F-18 LBDM Footprint Complexity

Prior to the Phase 2 flight test the following analyses will be pursued in Phase 2:

We will expand upon the Meteorological Assessment described in Appendix A. Our focus will be on the atmospheric effects upon footprint placement for both the focus and low boom and the associated overpressure values. This will include an investigation into upper air atmospheric data available for potential test sites to derive nominal seasonal data as well as minimum/maximum wind envelopes.

We will explore the ability of pilots to repeat the maneuver to deliver the prescribed effects and the influence of the atmosphere upon their ability to execute the maneuver. Both these efforts will require information furnished by NASA consisting of:

- Collection of historical as-flown F-18 dive trajectories
- Any existing analyses which provide low boom dive placement success rates

Environmental data associated with these historical flights.

Analysis of the Phase 2 low boom delivered over the non-acclimated community will be conducted in the same manner as done for WSPR 2011 with the exception that noise at a participant's location will be accomplished as described in section 9.1.3.

A database of all measurements, metrics calculated, and noise estimates at the participants' locations will be compiled and delivered as specified in the Statement of Work.

11.4 Data Analysis and Final Report

A complete statistical analysis correlating the objective measurements and subjective response will be conducted as described in Section 9.

12. Recommended Phase 2 Activities Beyond the Proposed Scope of Phase 2

The original solicitation (ROA-2014) specified the following: "Proposals for this topic should consist of two phases. The first phase should address the creation of a conceptual plan for a community response test, and the identification of risk and development areas associated with such a test. The second phase should address the reduction of one or more of the high priority risk areas through additional research or experimentation." Additionally ROA-2014 specified an estimated level of effort for Phase 2 to be "…two years at approximately $450K per year." Staying within this constraint, our original proposal included preparations for and execution of a Risk Reduction Community Response Test using a F-18 executing a Low Boom Dive Maneuver as this would provide the greatest return on the Phase 2 investment. The following efforts are recommended in addition to those activities described in section 11. Cost proposals for these efforts will be available for NASA upon request.

1. Design, development and validation of Low Cost Noise Monitors (Section 6.1.2)
2. Networked weather stations for each selected community (Section 6.2.1)
3. Numerical weather modelling
4. Armstrong Pre-Test

12.1 Design, development and validation of Low Cost Noise Monitors

A conceptual design for Low Cost Noise Monitors was presented in Section 6.1.2. Feasability testing of this conceptual design using available COTS components has been accomplished, however final engineering design, software development, prototyping and validation effort remains. Figure 12-1 Low Cost Noise Monitor Design, Prototype Production and Validationpresents the plan for development of the prototype system. This plan would support the production of a three instances of this prototype to support validation. Validation of these monitors would consist of comparisons with the SBUDAS Field Kits in the Gulfstream SASS II simulator and additionally they would be tested in the field. LCNM test objectives would include (1) evaluation of their ability to detect turbulence as compared with the SBUDAS field kits and (2) exploration of T. Marston's approach for low-frequency response extension for condenser microphones.

Collocated pairs of sensors consisting of one SBUDAS field kit and one LCNM would be positioned in an L configuration with 100 ft. separation in the vicinity of EAFB during planned supersonic overflight operations (**Figure 12-2**).

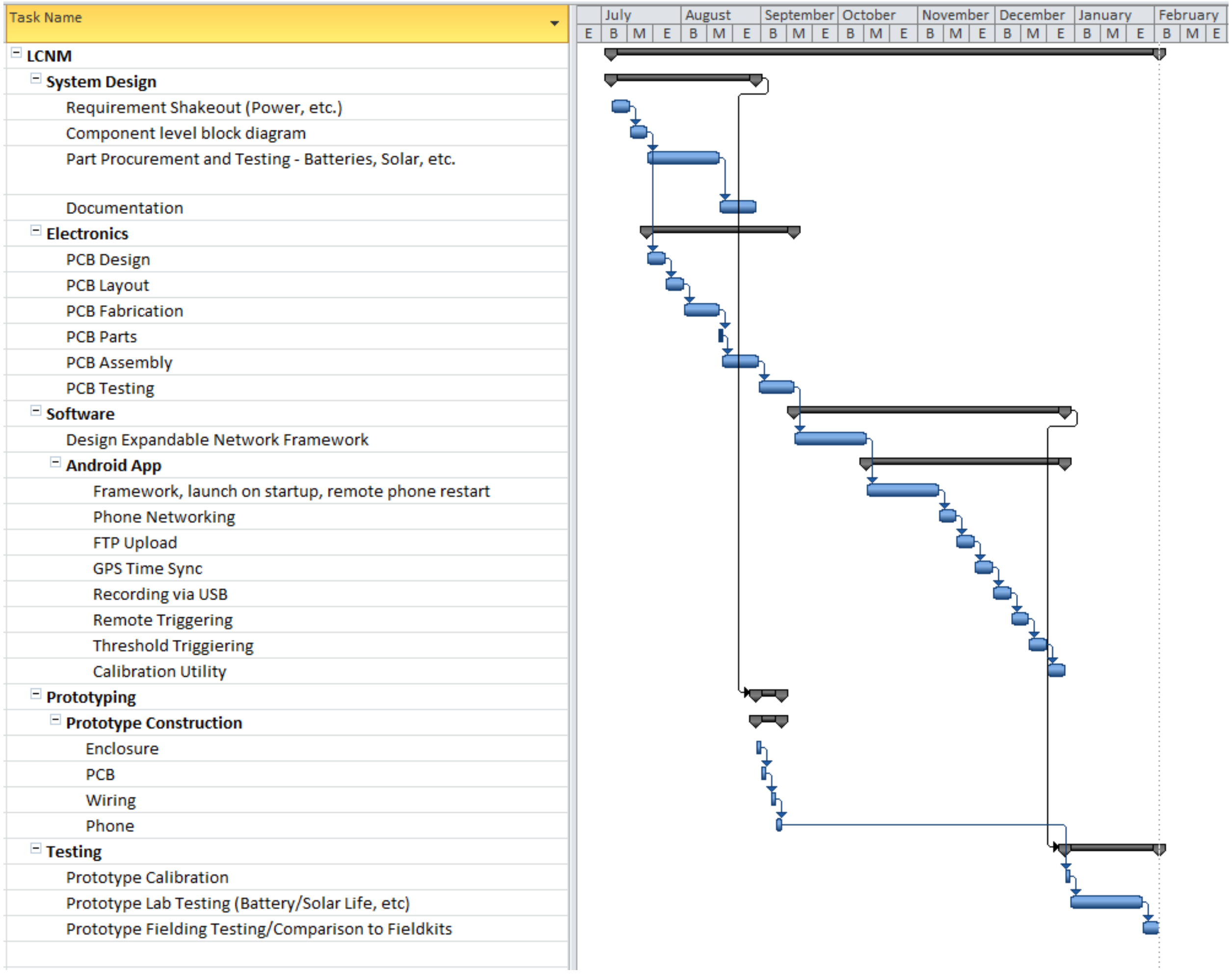


Figure 12-1 Low Cost Noise Monitor Design, Prototype Production and Validation

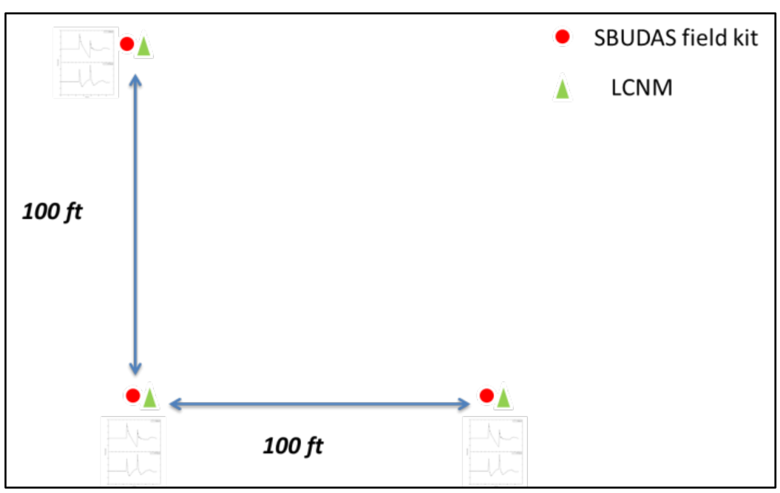


Figure 12-2 SBUDAS field kits and LCNMs arranged for an assessment of ability to detect turbulence

A second test with one set of the sensors sufficiently removed (more than a mile as shown in **Figure 12-3**) from the other two sensors would then be conducted to ensure that the initially computed LFTF is not affected by repositioning the sensor.

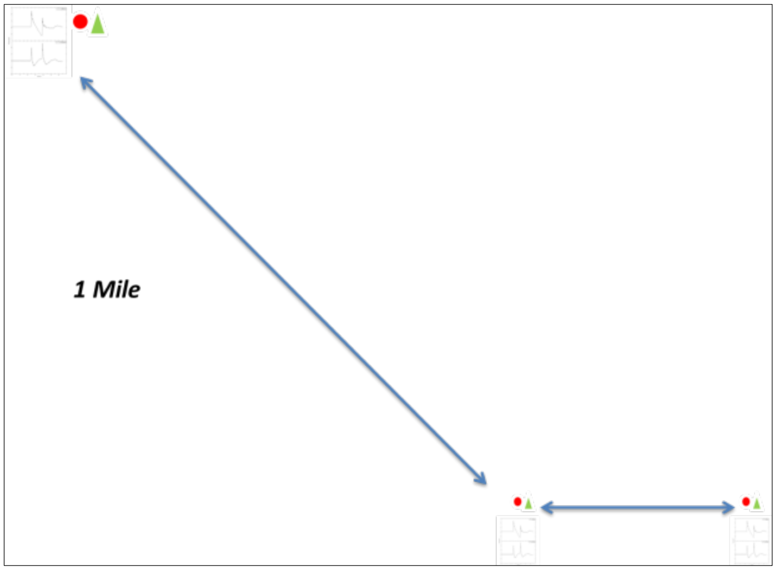


Figure 12-3 Assessment of the low frequency transfer function computed between sensors far removed

Detection of Turbulence –The Stevens MK VII loudness levels from multiple sonic booms would be compared between the sensors to assess the ability of the LCNMs to detect turbulence.

Low-Frequency Response Extension- The Low Frequency Transfer Function (LFTF) for the three prototype LCNMs would be determined in a laboratory setting prior to their deployment in the field. We will review the consistency of the LFTF between the three LCNMs to determine whether this process is required for each unit or whether it can be done once for the design. The measures utilized to assess detection of turbulence would then be utilized to compute the LFTF to determine if it is consistent with the LFTF determined using a calibrated signal in a laboratory environment.

The LFTF would then be applied to the data collected using the LCNMs for a comparison of the resultant waveforms to those collected by the SBUDAS field kits to assess the extent to which the true signature waveform could be recovered over the course of multiple sonic booms.

12.2 Networked weather stations for each selected community (Section 6.2.1)

As recommended in section 6.2.1, stand alone weather stations would improve the availability of surface weather conditions in each of the subject communities. This information will be valuable in the assessment of turbulence and their affect. These instruments support TCP/IP interfaces and could be easily networked within the objective sensor architecture for remote data access and archive.

12.3 Numerical weather modelling

As discussed in section 9.1.4, we are working with Naval Research Laboratory, Monterey CA (NRLMRY) to support the Phase 2 candidate sites with high resolution modelling utilizing COAMPS™ On Scene. As discussed in section 9.1.4, COAMPS On Scene is a numerical modeling infrastructure that can develop high resolution (temporal and spatial) solutions for small focused areas; NOAA numerical weather modeling is focused on a regional scale that is not sufficient for our purposes. This was not originally part of our proposed approach and was not considered in our proposed Phase 2 costs. Our point of contact at NRLMRY, (Chad Hutchins, Meteorologist) has advised us that NRLMRY support would consist of the following:

1. Enhance COAMPS-OS by creating webservice that can accept the rawinsonde and surface observations recorded during WSPRRR test events
2. Enhance the COAMPS OS™ analysis infrastructure to support ingest of insitu measurements received via this webservice
3. Ensure connectivity to the NRLMRY network by the WSPRRR team
4. Setup, maintain and run COAMPS OS™ over the required date/time periods using the observations obtained from WSPRRR
5. Provide desired meteorological analysis and forecasts fields in a timely manner
6. Provide routine maintenance/support of COAMPS OS™ runs.

If this support is desired by NASA it is recommended that it be negotiated by NASA separate to our contract as inter-agency support (Government to Government).

Provided that this effort can be supported the plan is that NRLMRY will initially establish a COAMPS™ On Scene model run across a preferred Phase 2 Candidate Site to generate four hour forecasts of the following parameters at a 1KM spatial resolution for the maximum number of levels the model can support from the surface to 60 kft:

- Pressure
- Temperature
- Relative Humidity
- Wind (speed and direction)
- Turbulence (as measured in Total Kinetic Energy)

The model will be run three times daily with analysis times for these runs of 0800, 1200, and 1600 local time of the Phase 2 candidate site. The model outputs will be made available for download via FTP and provide insight into the spatial and temporal variation of the weather across the area. They will be compared with available insitu measurements and additionally vertical atmospheric profiles will be constructed from this data for assessment of their utility to support PCBoom analysis.

Provided that this initial assessment of the contribution of numerical weather predictions is successful the model will then be utilized in support of the Phase 2 test. Data formats and transfer methods will be negotiated NRLMRY so that insitu measurements on the day of the flight can be uploaded and assimilated into their model runs. Outputs will be made available for consideration by flight planners and archived to support posttest analysis.

12.4 Armstrong Pre-Test

It is recommended that critical methods planned for employment in the Phase 2 test event be explored and refined prior to its execution. A limited objective test is recommended to be conducted at NASA Armstrong in May of 2017 prior to the Phase 2 F-18 LBDM over a Non Acclimated Community currently planned for November of 2017 (Figure 11-5). This test is required to explore the following:

- Survey design and implementation-This includes a survey response design assessment, testing the push notification, which are texts sent a half hour before a boom to prompt attentive listening. It also includes a test of the participant location using the Qualtrics GPS application and survey response data from the phone. The survey completion and submission parameters will be assessed as well. Some design changes may be made to survey submission parameters, or survey response instruments as an outcome of this test.
- Risk #27 Participant Location Determination – We intend to employ both survey design as well as GPS data collection through the Qualtrics Survey App (as approved by participants). We plan to conduct additional testing of GPS accuracy prior to conducting the Armstrong test.
- Risk #23 No Subjective Response – Given that the low boom is designed to be unobtrusive we must explore methods to ensure active listening on the part of participants so that we can clarify if they were listening and weren't bothered, didn't hear it and why. We intend to ensure attentive listening on the part of participants through text prompts prior to the low boom exposure. The text messages will be sent shortly before booms asking participants to "Please listen attentively for booms". This prompt will be sent before booms, and also at times when no booms will be present to ensure that the response is to the boom and not the text message. This design element will be clearly explained in the Informed Consent.
- Risk #33 Determination of Noise Dose at the Participant Location – We would validate the method described in Section 9.1.3 in a similar manner as was accomplished during WSPR 2011. We would select a noise monitor which would be removed from the total array of noise monitors and then using the remaining measurements we would calculate the noise expected at that monitor and compare it to the actual measurement of the monitor.

This limited objective test was not scoped as part of our original proposal submitted in May of 2014. We have attempted to quantify this test to assess the costs that it would introduce for both our team and NASA.

As previously described, the following risks could be explored through a series of smaller scale test events or in some cases through analysis of archived results from previous tests; nonetheless a limited objective test would provide an excellent opportunity for further exploration of our mitigation strategies associated with:

- Risk #8 Noise Monitoring Across Large Carpet Region and Risk #9 Unattended/Remote Controlled Noise Monitors- We would enhance the existing field kits and additionally integrate prototype low cost noise monitors for operating across a cellular VPN with automated data transfer to a central base station. We would deploy the high fidelity SBUDAS Field Kits for the collection of noise measurements in the area of the F-18 Low Boom Footprint.

- Risk #34 F-18 LBDM Footprint Complexity – We would refine and validate our methods for predicting placement of the focus region and low boom region resulting from an F-18 LBDM.
- Risk #31 F-18 LBDM Low Boom Intensity and Signature – The low boom signature resulting from an F-18 LBDM is of a greater intensity and has a different signature than what is expected from the LBFD. During the event we would explore the extent to which this simulation would differ from an LBFD and what would be the public response to it.
- Risk #6 Turbulence Detection – Specifically we would explore the ability to detect atmospheric turbulence using low cost noise monitors. We would deploy two Low Cost Noise Monitors in an L configuration with 100 foot separation to assess their ability to detect turbulence. A High Fidelity SBUDAS field kit would be placed at the corner of the L configuration for performance comparisons between the two types of sensors. This could additionally be utilized to assess the viability of extending the low frequency response of the low cost noise monitors as described in "Diffraction Correction and Low-Frequency Response Extension for Condenser Microphones" by Timothy Marston (PSU 2006).

We anticipate a test to be scheduled over the course of a one week period to allow for "no fly" periods. Ideally we would like 2-3 booms collected in the morning, mid-day, and late afternoon on each of three consecutive flight days. Low booms delivered during each of these periods would be separated by at least 20 minutes, preferably 30 minutes for a total of 9 booms/day for three days or 27 low booms total. We would recruit 30 participants to support collection on the order of 600-800 responses for statistical purposes.

13. Summary and Next Steps

This document captures our current LBFD Test design and reflects the work we have done in laying out an experiment to obtain low-boom dose-response data to inform the regulatory process. Currently the design is structured so that the anticipated results will capture single event annoyance as well as cumulative annoyance. The test plan has been structured to facilitate analysis which will help to explain potential differences in responses across multiple communities.

Present design elements encapsulate a variety of elements with various degrees of refinement and include the following:

- Site Selection
    - Regional Site Selection
    - Prominent Community Selection
    - Flight path design
- Subjective Elements
    - Recruitment Plan
    - Survey Instruments
    - Techniques for introduction of a new noise source
- Objective Noise Design
    - Noise dose exposure
    - Acoustic monitors: layout and instrumentation design
    - Weather data and instrumentation needs
- Communications Plan

Throughout our spiral design process we have carefully identified and tracked risks and assessed the probability and consequences and will continue to do so as we further refine the LBFD test plan. The risks of significant impact are identified in Section 10 and revolve primarily around the subjects' locations at the time of the noise exposure and their response. The focus of our continued test plan development includes the following items:

- Development of a statistical analysis model to compare dose-response across communities
- Refinement of the community selection process and identification of specific criteria (both for single sites and across all regional sites) especially those items driven by statistical analysis requirements, anticipation of regulatory needs and identified risks.
- Refinement of the methods and design to acquire the noise dose including acoustic measurements, techniques for accounting for turbulence, leveraging PCBoom analysis capabilities, understanding of the uncertainties and instrumentation options that minimize cost.
- Layout of regional flight tracks which encompass noise dose design and approximate LBFD aero-performance and low-boom performance including climb and turn maneuvers.

Based on the risk outcomes we have developed synergistic phase 2 activities tailored for reducing risk as described in Section 11 including a F18 dive test over a non-acclimated community. These are being optimized and planned in more detail to further reduce risks and costs for each activity.

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Appendices

A. Prominent Community Demographics

The selected prominent communities have been examined in sufficient detail to ensure that they meet the selection process (Section 3). Sections A.1 through A.6 contain detailed demographics information based on the US 2010 Census data for each of the selected prominent communities in each of the six climate zones.

A.1 Hot-Humid Region, Central Florida

Orlando City

Population by Sex/Age		
Male	115,883	48.63%
Female	122,417	51.37%
Under 18	52,297	21.95%
18 & over	186,003	78.05%
20 - 24	20,946	8.79%
25 - 34	48,976	20.55%
35 - 49	52,236	21.92%
50 - 64	35,714	14.99%
65 & over	22,408	9.40%
Population by Ethnicity		
Hispanic or Latino	60,483	25.38%
Non Hispanic or Latino	177,817	74.62%
Population by Race		
White	137,159	57.56%
African American	66,876	28.06%
Asian	8,944	3.75%
American Indian and Alaska Native	902	0.38%
Native Hawaiian and Pacific Islander	183	0.08%
Other	16,091	6.75%
Identified by two or more	8,145	3.42%

Eustis City

Population by Sex/Age		
Male	8,740	47.10%
Female	9,818	52.90%
Under 18	4,336	23.36%
18 & over	14,222	76.64%
20 - 24	1,027	5.53%
25 - 34	2,110	11.37%
35 - 49	3,334	17.97%
50 - 64	3,433	18.50%
65 & over	3,866	20.83%
Population by Ethnicity		
Hispanic or Latino	2,202	11.87%
Non Hispanic or Latino	16,356	88.13%
Population by Race		
White	13,893	74.86%
African American	3,229	17.40%
Asian	215	1.16%
American Indian and Alaska Native	78	0.42%
Native Hawaiian and Pacific Islander	1	0.01%
Other	704	3.79%
Identified by two or more	438	2.36%

Clermont City

Population by Sex/Age		
Male	13,597	47.31%
Female	15,145	52.69%
Under 18	6,762	23.53%
18 & over	21,980	76.47%
20 - 24	1,489	5.18%
25 - 34	3,094	10.76%
35 - 49	5,973	20.78%
50 - 64	4,970	17.29%
65 & over	5,757	20.03%
Population by Ethnicity		
Hispanic or Latino	5,102	17.75%
Non Hispanic or Latino	23,640	82.25%
Population by Race		
White	20,606	71.69%
African American	4,141	14.41%
Asian	1,203	4.19%
American Indian and Alaska Native	120	0.42%
Native Hawaiian and Pacific Islander	27	0.09%
Other	1,543	5.37%
Identified by two or more	1,102	3.83%

Sanford City

Population by Sex/Age		
Male	25,717	48.01%
Female	27,853	51.99%
Under 18	13,954	26.05%
18 & over	39,616	73.95%
20 - 24	4,409	8.23%
25 - 34	9,042	16.88%
35 - 49	11,084	20.69%
50 - 64	8,507	15.88%
65 & over	4,999	9.33%
Population by Ethnicity		
Hispanic or Latino	10,844	20.24%
Non Hispanic or Latino	42,726	79.76%
Population by Race		
White	30,714	57.33%
African American	16,332	30.49%
Asian	1,504	2.81%
American Indian and Alaska Native	291	0.54%
Native Hawaiian and Pacific Islander	44	0.08%
Other	2,911	5.43%
Identified by two or more	1,774	3.31%

The Villages CDP

Population by Sex/Age		
Male	24,069	46.79%
Female	27,373	53.21%
Under 18	139	0.27%
18 & over	51,303	99.73%
20 - 24	98	0.19%
25 - 34	242	0.47%
35 - 49	801	1.56%
50 - 64	14,254	27.71%
65 & over	35,893	69.77%
Population by Ethnicity		
Hispanic or Latino	768	1.49%
Non Hispanic or Latino	50,674	98.51%
Population by Race		
White	50,511	98.19%
African American	314	0.61%
Asian	342	0.66%
American Indian and Alaska Native	52	0.10%
Native Hawaiian and Pacific Islander	11	0.02%
Other	64	0.12%
Identified by two or more	148	0.29%

Titusville

Population by Sex/Age		
Male	21,057	48.12%
Female	22,704	51.88%
Under 18	8,991	20.55%
18 & over	34,770	79.45%
20 - 24	2,462	5.63%
25 - 34	4,861	11.11%
35 - 49	8,403	19.20%
50 - 64	9,008	20.58%
65 & over	8,979	20.52%
Population by Ethnicity		
Hispanic or Latino	2,825	6.46%
Non Hispanic or Latino	40,936	93.54%
Population by Race		
White	35,375	80.84%
African American	5,909	13.50%
Asian	608	1.39%
American Indian and Alaska Native	206	0.47%
Native Hawaiian and Pacific Islander	41	0.09%
Other	513	1.17%
Identified by two or more	1,109	2.53%

Oak Hill City

Population by Sex/Age		
Male	907	50.61%
Female	885	49.39%
Under 18	303	16.91%
18 & over	1,489	83.09%
20 - 24	89	4.97%
25 - 34	128	7.14%
35 - 49	298	16.63%
50 - 64	501	27.96%
65 & over	439	24.50%
Population by Ethnicity		
Hispanic or Latino	31	1.73%
Non Hispanic or Latino	1,761	98.27%
Population by Race		
White	1,490	83.15%
African American	249	13.90%
Asian	9	0.50%
American Indian and Alaska Native	8	0.45%
Native Hawaiian and Pacific Islander	0	0.00%
Other	5	0.28%
Identified by two or more	31	1.73%

Four Corners CDP

Population by Sex/Age		
Male	12,695	48.61%
Female	13,421	51.39%
Under 18	6,193	23.71%
18 & over	19,923	76.29%
20 - 24	1,621	6.21%
25 - 34	3,951	15.13%
35 - 49	5,689	21.78%
50 - 64	4,724	18.09%
65 & over	3,316	12.70%
Population by Ethnicity		
Hispanic or Latino	7,859	30.09%
Non Hispanic or Latino	18,257	69.91%
Population by Race		
White	19,870	76.08%
African American	2,092	8.01%
Asian	648	2.48%
American Indian and Alaska Native	142	0.54%
Native Hawaiian and Pacific Islander	36	0.14%
Other	2,412	9.24%
Identified by two or more	916	3.51%

Dade City

Population by Sex/Age		
Male	2,931	45.53%
Female	3,506	54.47%
Under 18	1,575	24.47%
18 & over	4,862	75.53%
20 - 24	481	7.47%
25 - 34	739	11.48%
35 - 49	1,170	18.18%
50 - 64	1,129	17.54%
65 & over	1,127	17.51%
Population by Ethnicity		
Hispanic or Latino	1,329	20.65%
Non Hispanic or Latino	5,108	79.35%
Population by Race		
White	4,335	67.35%
African American	1,316	20.44%
Asian	28	0.43%
American Indian and Alaska Native	27	0.42%
Native Hawaiian and Pacific Islander	10	0.16%
Other	557	8.65%
Identified by two or more	164	2.55%

Webster

Population by Sex/Age		
Male	389	49.55%
Female	396	50.45%
Under 18	234	29.81%
18 & over	551	70.19%
20 - 24	38	4.84%
25 - 34	100	12.74%
35 - 49	133	16.94%
50 - 64	147	18.73%
65 & over	96	12.23%
Population by Ethnicity		
Hispanic or Latino	215	27.39%
Non Hispanic or Latino	570	72.61%
Population by Race		
White	417	53.12%
African American	241	30.70%
Asian	1	0.13%
American Indian and Alaska Native	2	0.25%
Native Hawaiian and Pacific Islander	2	0.25%
Other	93	11.85%
Identified by two or more	29	3.69%

Kissimmee

Population by Sex/Age			
Male	29,020		48.62%
Female	30,662		51.38%
Under 18	15,337		25.70%
18 & over	44,345		74.30%
20 - 24	4,808		8.06%
25 - 34	9,068		15.19%
35 - 49	13,199		22.12%
50 - 64	9,774		16.38%
65 & over	5,620		9.42%
Population by Ethnicity			
Hispanic or Latino	35,170		58.93%
Non Hispanic or Latino	24,512		41.07%
Population by Race			
White	39,431		66.07%
African American	7,386		12.38%
Asian	2,005		3.36%
American Indian and Alaska Native	349		0.58%
Native Hawaiian and Pacific Islander	50		0.08%
Other	7,674		12.86%
Identified by two or more	2,787		4.67%

Port St. John

Population by Sex/Age			
Male	6,106		49.78%
Female	6,161		50.22%
Under 18	2,780		22.66%
18 & over	9,487		77.34%
20 - 24	662		5.40%
25 - 34	1,359		11.08%
35 - 49	2,922		23.82%
50 - 64	2,686		21.90%
65 & over	1,515		12.35%
Population by Ethnicity			
Hispanic or Latino	737		6.01%
Non Hispanic or Latino	11,530		93.99%
Population by Race			
White	10,977		89.48%
African American	674		5.49%
Asian	121		0.99%
American Indian and Alaska Native	64		0.52%
Native Hawaiian and Pacific Islander	37		0.30%
Other	106		0.86%
Identified by two or more	288		2.35%

A.2 Marine Region – Seattle/Tacoma, WA

Copalis Beach

Population by Sex/Age		
Male	210	50.60%
Female	205	49.40%
Under 18	58	13.98%
18 & over	357	86.02%
20 - 24	27	6.51%
25 - 34	30	7.23%
35 - 49	75	18.07%
50 - 64	119	28.67%
65 & over	100	24.10%
Population by Ethnicity		
Hispanic or Latino	9	2.17%
Non Hispanic or Latino	406	97.83%
Population by Race		
White	365	87.95%
African American	3	0.72%
Asian	3	0.72%
American Indian and Alaska Native	22	5.30%
Native Hawaiian and Pacific Islander	0	0.00%
Other	5	1.20%
Identified by two or more	17	4.10%

Ocean Shores

Population by Sex/Age		
Male	2,690	48.30%
Female	2,879	51.70%
Under 18	703	12.62%
18 & over	4,866	87.38%
20 - 24	184	3.30%
25 - 34	343	6.16%
35 - 49	761	13.66%
50 - 64	1,760	31.60%
65 & over	1,731	31.08%
Population by Ethnicity		
Hispanic or Latino	178	3.20%
Non Hispanic or Latino	5,391	96.80%
Population by Race		
White	5,024	90.21%
African American	51	0.92%
Asian	97	1.74%
American Indian and Alaska Native	117	2.10%
Native Hawaiian and Pacific Islander	11	0.20%
Other	36	0.65%
Identified by two or more	233	4.18%

Grayland

Population by Sex/Age		
Male	472	49.53%
Female	481	50.47%
Under 18	113	11.86%
18 & over	840	88.14%
20 - 24	24	2.52%
25 - 34	55	5.77%
35 - 49	147	15.42%
50 - 64	335	35.15%
65 & over	257	26.97%
Population by Ethnicity		
Hispanic or Latino	40	4.20%
Non Hispanic or Latino	913	95.80%
Population by Race		
White	871	91.40%
African American	3	0.31%
Asian	11	1.15%
American Indian and Alaska Native	28	2.94%
Native Hawaiian and Pacific Islander	0	0.00%
Other	13	1.36%
Identified by two or more	27	2.83%

Aberdeen Gardens

Population by Sex/Age		
Male	139	49.82%
Female	140	50.18%
Under 18	59	21.15%
18 & over	220	78.85%
20 - 24	15	5.38%
25 - 34	25	8.96%
35 - 49	61	21.86%
50 - 64	77	27.60%
65 & over	34	12.19%
Population by Ethnicity		
Hispanic or Latino	14	5.02%
Non Hispanic or Latino	265	94.98%
Population by Race		
White	254	91.04%
African American	0	0.00%
Asian	6	2.15%
American Indian and Alaska Native	5	1.79%
Native Hawaiian and Pacific Islander	0	0.00%
Other	0	0.00%
Identified by two or more	14	5.02%

Aberdeen

Population by Sex/Age		
Male	8,421	49.84%
Female	8,475	50.16%
Under 18	4,206	24.89%
18 & over	12,690	75.11%
20 - 24	1,250	7.40%
25 - 34	2,348	13.90%
35 - 49	3,113	18.42%
50 - 64	3,278	19.40%
65 & over	2,192	12.97%
Population by Ethnicity		
Hispanic or Latino	2,678	15.85%
Non Hispanic or Latino	14,218	84.15%
Population by Race		
White	13,584	80.40%
African American	135	0.80%
Asian	319	1.89%
American Indian and Alaska Native	617	3.65%
Native Hawaiian and Pacific Islander	49	0.29%
Other	1,359	8.04%
Identified by two or more	833	4.93%

Elma

Population by Sex/Age		
Male	1,527	49.15%
Female	1,580	50.85%
Under 18	805	25.91%
18 & over	2,302	74.09%
20 - 24	206	6.63%
25 - 34	428	13.78%
35 - 49	572	18.41%
50 - 64	613	19.73%
65 & over	402	12.94%
Population by Ethnicity		
Hispanic or Latino	205	6.60%
Non Hispanic or Latino	2,902	93.40%
Population by Race		
White	2,666	85.81%
African American	32	1.03%
Asian	65	2.09%
American Indian and Alaska Native	82	2.64%
Native Hawaiian and Pacific Islander	11	0.35%
Other	100	3.22%
Identified by two or more	151	4.86%

Oakville

Population by Sex/Age		
Male	336	49.12%
Female	348	50.88%
Under 18	178	26.02%
18 & over	506	73.98%
20 - 24	33	4.82%
25 - 34	91	13.30%
35 - 49	134	19.59%
50 - 64	136	19.88%
65 & over	96	14.04%
Population by Ethnicity		
Hispanic or Latino	45	6.58%
Non Hispanic or Latino	639	93.42%
Population by Race		
White	592	86.55%
African American	4	0.58%
Asian	6	0.88%
American Indian and Alaska Native	35	5.12%
Native Hawaiian and Pacific Islander	1	0.15%
Other	28	4.09%
Identified by two or more	18	2.63%

Shelton

Population by Sex/Age		
Male	4,828	49.09%
Female	5,006	50.91%
Under 18	2,593	26.37%
18 & over	7,241	73.63%
20 - 24	770	7.83%
25 - 34	1,496	15.21%
35 - 49	1,721	17.50%
50 - 64	1,546	15.72%
65 & over	1,406	14.30%
Population by Ethnicity		
Hispanic or Latino	1,893	19.25%
Non Hispanic or Latino	7,941	80.75%
Population by Race		
White	7,763	78.94%
African American	82	0.83%
Asian	105	1.07%
American Indian and Alaska Native	359	3.65%
Native Hawaiian and Pacific Islander	78	0.79%
Other	969	9.85%
Identified by two or more	478	4.86%

Olympia			
Population by Sex/Age			
Male	21,961		47.25%
Female	24,517		52.75%
Under 18	9,064		19.50%
18 & over	37,414		80.50%
20 - 24	4,115		8.85%
25 - 34	7,179		15.45%
35 - 49	9,130		19.64%
50 - 64	9,422		20.27%
65 & over	6,459		13.90%
Population by Ethnicity			
Hispanic or Latino	2,919		6.28%
Non Hispanic or Latino	43,559		93.72%
Population by Race			
White	38,895		83.68%
African American	931		2.00%
Asian	2,799		6.02%
American Indian and Alaska Native	498		1.07%
Native Hawaiian and Pacific Islander	180		0.39%
Other	847		1.82%
Identified by two or more	2,328		5.01%

Grand Mound			
Population by Sex/Age			
Male	1,495		50.15%
Female	1,486		49.85%
Under 18	909		30.49%
18 & over	2,072		69.51%
20 - 24	148		4.96%
25 - 34	432		14.49%
35 - 49	619		20.76%
50 - 64	508		17.04%
65 & over	285		9.56%
Population by Ethnicity			
Hispanic or Latino	480		16.10%
Non Hispanic or Latino	2,501		83.90%
Population by Race			
White	2,438		81.78%
African American	21		0.70%
Asian	33		1.11%
American Indian and Alaska Native	63		2.11%
Native Hawaiian and Pacific Islander	6		0.20%
Other	248		8.32%
Identified by two or more	172		5.77%

A.3 Cold Region – Saginaw, MI

Bay City

Population by Sex/Age			
Male	17,019		48.72%
Female	17,913		51.28%
Under 18	8,683		24.86%
18 & over	26,249		75.14%
20 - 24	2,394		6.85%
25 - 34	5,046		14.45%
35 - 49	6,890		19.72%
50 - 64	6,614		18.93%
65 & over	4,286		12.27%
Population by Ethnicity			
Hispanic or Latino	2,970		8.50%
Non Hispanic or Latino	31,962		91.50%
Population by Race			
White	31,319		89.66%
African American	1,222		3.50%
Asian	159		0.46%
American Indian and Alaska Native	224		0.64%
Native Hawaiian and Pacific Islander	5		0.01%
Other	635		1.82%
Identified by two or more	1,368		3.92%

Freeland Twp

Population by Sex/Age			
Male	4,174		59.89%
Female	2,795		40.11%
Under 18	1,621		23.26%
18 & over	5,348		76.74%
20 - 24	532		7.63%
25 - 34	1,181		16.95%
35 - 49	1,802		25.86%
50 - 64	1,076		15.44%
65 & over	575		8.25%
Population by Ethnicity			
Hispanic or Latino	203		2.91%
Non Hispanic or Latino	6,766		97.09%
Population by Race			
White	5,905		84.73%
African American	870		12.48%
Asian	39		0.56%
American Indian and Alaska Native	32		0.46%
Native Hawaiian and Pacific Islander	3		0.04%
Other	39		0.56%
Identified by two or more	81		1.16%

Reese

Population by Sex/Age			
Male	685		47.11%
Female	769		52.89%
Under 18	328		22.56%
18 & over	1,126		77.44%
20 - 24	72		4.95%
25 - 34	165		11.35%
35 - 49	262		18.02%
50 - 64	329		22.63%
65 & over	263		18.09%
Population by Ethnicity			
Hispanic or Latino	62		4.26%
Non Hispanic or Latino	1,392		95.74%
Population by Race			
White	1,413		97.18%
African American	10		0.69%
Asian	10		0.69%
American Indian and Alaska Native	3		0.21%
Native Hawaiian and Pacific Islander	0		0.00%
Other	12		0.83%
Identified by two or more	6		0.41%

Bridgeport Twp

Population by Sex/Age			
Male	3,216		46.27%
Female	3,734		53.73%
Under 18	1,670		24.03%
18 & over	5,280		75.97%
20 - 24	416		5.99%
25 - 34	703		10.12%
35 - 49	1,297		18.66%
50 - 64	1,599		23.01%
65 & over	1,096		15.77%
Population by Ethnicity			
Hispanic or Latino	753		10.83%
Non Hispanic or Latino	6,197		89.17%
Population by Race			
White	3,990		57.41%
African American	2,470		35.54%
Asian	12		0.17%
American Indian and Alaska Native	29		0.42%
Native Hawaiian and Pacific Islander	0		0.00%
Other	228		3.28%
Identified by two or more	221		3.18%

Saginaw

Population by Sex/Age		
Male	24,264	47.11%
Female	27,244	52.89%
Under 18	14,650	28.44%
18 & over	36,858	71.56%
20 - 24	3,636	7.06%
25 - 34	6,674	12.96%
35 - 49	9,624	18.68%
50 - 64	9,509	18.46%
65 & over	5,635	10.94%
Population by Ethnicity		
Hispanic or Latino	7,344	14.26%
Non Hispanic or Latino	44,164	85.74%
Population by Race		
White	22,401	43.49%
African American	23,721	46.05%
Asian	165	0.32%
American Indian and Alaska Native	268	0.52%
Native Hawaiian and Pacific Islander	15	0.03%
Other	2,693	5.23%
Identified by two or more	2,245	4.36%

Millington

Population by Sex/Age		
Male	506	47.20%
Female	566	52.80%
Under 18	306	28.54%
18 & over	766	71.46%
20 - 24	78	7.28%
25 - 34	153	14.27%
35 - 49	190	17.72%
50 - 64	150	13.99%
65 & over	156	14.55%
Population by Ethnicity		
Hispanic or Latino	27	2.52%
Non Hispanic or Latino	1,045	97.48%
Population by Race		
White	1,017	94.87%
African American	16	1.49%
Asian	6	0.56%
American Indian and Alaska Native	6	0.56%
Native Hawaiian and Pacific Islander	0	0.00%
Other	10	0.93%
Identified by two or more	17	1.59%

Clio

Population by Sex/Age		
Male	1,248	47.17%
Female	1,398	52.83%
Under 18	642	24.26%
18 & over	2,004	75.74%
20 - 24	216	8.16%
25 - 34	356	13.45%
35 - 49	490	18.52%
50 - 64	445	16.82%
65 & over	410	15.50%
Population by Ethnicity		
Hispanic or Latino	84	3.17%
Non Hispanic or Latino	2,562	96.83%
Population by Race		
White	2,519	95.20%
African American	28	1.06%
Asian	5	0.19%
American Indian and Alaska Native	16	0.60%
Native Hawaiian and Pacific Islander	1	0.04%
Other	21	0.79%
Identified by two or more	56	2.12%

Flushing

Population by Sex/Age		
Male	3,864	46.06%
Female	4,525	53.94%
Under 18	1,821	21.71%
18 & over	6,568	78.29%
20 - 24	405	4.83%
25 - 34	814	9.70%
35 - 49	1,521	18.13%
50 - 64	1,796	21.41%
65 & over	1,820	21.70%
Population by Ethnicity		
Hispanic or Latino	181	2.16%
Non Hispanic or Latino	8,208	97.84%
Population by Race		
White	7,956	94.84%
African American	198	2.36%
Asian	37	0.44%
American Indian and Alaska Native	31	0.37%
Native Hawaiian and Pacific Islander	2	0.02%
Other	29	0.35%
Identified by two or more	136	1.62%

Davison

Population by Sex/Age		
Male	2,339	45.22%
Female	2,834	54.78%
Under 18	1,216	23.51%
18 & over	3,957	76.49%
20 - 24	281	5.43%
25 - 34	668	12.91%
35 - 49	1,011	19.54%
50 - 64	1,004	19.41%
65 & over	874	16.90%
Population by Ethnicity		
Hispanic or Latino	151	2.92%
Non Hispanic or Latino	5,022	97.08%
Population by Race		
White	4,907	94.86%
African American	92	1.78%
Asian	17	0.33%
American Indian and Alaska Native	17	0.33%
Native Hawaiian and Pacific Islander	1	0.02%
Other	34	0.66%
Identified by two or more	105	2.03%

Flint

Population by Sex/Age		
Male	49,140	47.97%
Female	53,294	52.03%
Under 18	27,914	27.25%
18 & over	74,520	72.75%
20 - 24	7,735	7.55%
25 - 34	13,443	13.12%
35 - 49	19,856	19.38%
50 - 64	18,651	18.21%
65 & over	10,999	10.74%
Population by Ethnicity		
Hispanic or Latino	3,976	3.88%
Non Hispanic or Latino	98,458	96.12%
Population by Race		
White	38,328	37.42%
African American	57,939	56.56%
Asian	464	0.45%
American Indian and Alaska Native	550	0.54%
Native Hawaiian and Pacific Islander	16	0.02%
Other	1,169	1.14%
Identified by two or more	3,968	3.87%

Swartz Creek

Population by Sex/Age		
Male	2,579	44.79%
Female	3,179	55.21%
Under 18	1,304	22.65%
18 & over	4,454	77.35%
20 - 24	294	5.11%
25 - 34	665	11.55%
35 - 49	1,108	19.24%
50 - 64	1,100	19.10%
65 & over	1,159	20.13%
Population by Ethnicity		
Hispanic or Latino	130	2.26%
Non Hispanic or Latino	5,628	97.74%
Population by Race		
White	5,277	91.65%
African American	292	5.07%
Asian	46	0.80%
American Indian and Alaska Native	12	0.21%
Native Hawaiian and Pacific Islander	0	0.00%
Other	27	0.47%
Identified by two or more	104	1.81%

n/a

A.4 Cold Region – Upstate NY

N. Syracuse

Population by Sex/Age		
Male	3,283	48.28%
Female	3,517	51.72%
Under 18	1,430	21.03%
18 & over	5,370	78.97%
20 - 24	407	5.99%
25 - 34	910	13.38%
35 - 49	1,401	20.60%
50 - 64	1,272	18.71%
65 & over	1,229	18.07%
Population by Ethnicity		
Hispanic or Latino	177	2.60%
Non Hispanic or Latino	6,623	97.40%
Population by Race		
White	6,369	93.66%
African American	154	2.26%
Asian	49	0.72%
American Indian and Alaska Native	54	0.79%
Native Hawaiian and Pacific Islander	3	0.04%
Other	53	0.78%
Identified by two or more	118	1.74%

Syracuse

Population by Sex/Age		
Male	69,180	47.65%
Female	75,990	52.35%
Under 18	33,433	23.03%
18 & over	111,737	76.97%
20 - 24	19,237	13.25%
25 - 34	21,545	14.84%
35 - 49	24,364	16.78%
50 - 64	22,782	15.69%
65 & over	15,340	10.57%
Population by Ethnicity		
Hispanic or Latino	12,036	8.29%
Non Hispanic or Latino	133,134	91.71%
Population by Race		
White	81,319	56.02%
African American	42,770	29.46%
Asian	8,021	5.53%
American Indian and Alaska Native	1,606	1.11%
Native Hawaiian and Pacific Islander	44	0.03%
Other	3,937	2.71%
Identified by two or more	7,473	5.15%

Cleveland

Population by Sex/Age		
Male	386	51.47%
Female	364	48.53%
Under 18	192	25.60%
18 & over	558	74.40%
20 - 24	38	5.07%
25 - 34	93	12.40%
35 - 49	151	20.13%
50 - 64	164	21.87%
65 & over	92	12.27%
Population by Ethnicity		
Hispanic or Latino	9	1.20%
Non Hispanic or Latino	741	98.80%
Population by Race		
White	729	97.20%
African American	3	0.40%
Asian	7	0.93%
American Indian and Alaska Native	5	0.67%
Native Hawaiian and Pacific Islander	0	0.00%
Other	3	0.40%
Identified by two or more	3	0.40%

Chittenango

Population by Sex/Age		
Male	2,392	47.08%
Female	2,689	52.92%
Under 18	1,271	25.01%
18 & over	3,810	74.99%
20 - 24	245	4.82%
25 - 34	591	11.63%
35 - 49	1,136	22.36%
50 - 64	1,062	20.90%
65 & over	661	13.01%
Population by Ethnicity		
Hispanic or Latino	89	1.75%
Non Hispanic or Latino	4,992	98.25%
Population by Race		
White	4,886	96.16%
African American	54	1.06%
Asian	23	0.45%
American Indian and Alaska Native	34	0.67%
Native Hawaiian and Pacific Islander	0	0.00%
Other	5	0.10%
Identified by two or more	79	1.55%

Cazenovia

Population by Sex/Age		
Male	1,141	40.25%
Female	1,694	59.75%
Under 18	440	15.52%
18 & over	2,395	84.48%
20 - 24	601	21.20%
25 - 34	187	6.60%
35 - 49	360	12.70%
50 - 64	459	16.19%
65 & over	431	15.20%
Population by Ethnicity		
Hispanic or Latino	85	3.00%
Non Hispanic or Latino	2,750	97.00%
Population by Race		
White	2,688	94.81%
African American	55	1.94%
Asian	32	1.13%
American Indian and Alaska Native	8	0.28%
Native Hawaiian and Pacific Islander	0	0.00%
Other	20	0.71%
Identified by two or more	32	1.13%

Sylvan Beach

Population by Sex/Age		
Male	444	49.50%
Female	453	50.50%
Under 18	136	15.16%
18 & over	761	84.84%
20 - 24	25	2.79%
25 - 34	93	10.37%
35 - 49	180	20.07%
50 - 64	243	27.09%
65 & over	204	22.74%
Population by Ethnicity		
Hispanic or Latino	7	0.78%
Non Hispanic or Latino	890	99.22%
Population by Race		
White	880	98.10%
African American	6	0.67%
Asian	2	0.22%
American Indian and Alaska Native	4	0.45%
Native Hawaiian and Pacific Islander	0	0.00%
Other	0	0.00%
Identified by two or more	5	0.56%

Oneida

Population by Sex/Age		
Male	5,512	48.38%
Female	5,881	51.62%
Under 18	2,688	23.59%
18 & over	8,705	76.41%
20 - 24	634	5.56%
25 - 34	1,369	12.02%
35 - 49	2,477	21.74%
50 - 64	2,292	20.12%
65 & over	1,665	14.61%
Population by Ethnicity		
Hispanic or Latino	165	1.45%
Non Hispanic or Latino	11,228	98.55%
Population by Race		
White	10,722	94.11%
African American	138	1.21%
Asian	87	0.76%
American Indian and Alaska Native	234	2.05%
Native Hawaiian and Pacific Islander	4	0.04%
Other	39	0.34%
Identified by two or more	169	1.48%

Morrisville

Population by Sex/Age		
Male	1,132	51.48%
Female	1,067	48.52%
Under 18	180	8.19%
18 & over	2,019	91.81%
20 - 24	643	29.24%
25 - 34	110	5.00%
35 - 49	161	7.32%
50 - 64	156	7.09%
65 & over	227	10.32%
Population by Ethnicity		
Hispanic or Latino	147	6.68%
Non Hispanic or Latino	2,052	93.32%
Population by Race		
White	1,605	72.99%
African American	449	20.42%
Asian	30	1.36%
American Indian and Alaska Native	9	0.41%
Native Hawaiian and Pacific Islander	0	0.00%
Other	57	2.59%
Identified by two or more	49	2.23%

Rome

Population by Sex/Age		
Male	17,324	51.37%
Female	16,401	48.63%
Under 18	7,037	20.87%
18 & over	26,688	79.13%
20 - 24	2,271	6.73%
25 - 34	4,668	13.84%
35 - 49	6,691	19.84%
50 - 64	6,701	19.87%
65 & over	5,559	16.48%
Population by Ethnicity		
Hispanic or Latino	1,793	5.32%
Non Hispanic or Latino	31,932	94.68%
Population by Race		
White	29,483	87.42%
African American	2,394	7.10%
Asian	367	1.09%
American Indian and Alaska Native	115	0.34%
Native Hawaiian and Pacific Islander	1	0.00%
Other	470	1.39%
Identified by two or more	895	2.65%

Utica

Population by Sex/Age		
Male	29,924	48.08%
Female	32,311	51.92%
Under 18	15,386	24.72%
18 & over	46,849	75.28%
20 - 24	5,179	8.32%
25 - 34	8,173	13.13%
35 - 49	11,184	17.97%
50 - 64	10,550	16.95%
65 & over	9,221	14.82%
Population by Ethnicity		
Hispanic or Latino	6,555	10.53%
Non Hispanic or Latino	55,680	89.47%
Population by Race		
White	42,945	69.00%
African American	9,501	15.27%
Asian	4,626	7.43%
American Indian and Alaska Native	180	0.29%
Native Hawaiian and Pacific Islander	36	0.06%
Other	2,441	3.92%
Identified by two or more	2,506	4.03%

Waterville

Population by Sex/Age		
Male	755	47.69%
Female	828	52.31%
Under 18	369	23.31%
18 & over	1,214	76.69%
20 - 24	85	5.37%
25 - 34	175	11.05%
35 - 49	295	18.64%
50 - 64	314	19.84%
65 & over	313	19.77%
Population by Ethnicity		
Hispanic or Latino	16	1.01%
Non Hispanic or Latino	1,567	98.99%
Population by Race		
White	1,535	96.97%
African American	4	0.25%
Asian	6	0.38%
American Indian and Alaska Native	3	0.19%
Native Hawaiian and Pacific Islander	9	0.57%
Other	1	0.06%
Identified by two or more	25	1.58%

A.5 Mixed Region– VA/MD/DE

Princess Anne, MD

Population by Sex/Age		
Male	1,319	40.09%
Female	1,971	59.91%
Under 18	710	21.58%
18 & over	2,580	78.42%
20 - 24	556	16.90%
25 - 34	466	14.16%
35 - 49	478	14.53%
50 - 64	417	12.67%
65 & over	266	8.09%
Population by Ethnicity		
Hispanic or Latino	94	2.86%
Non Hispanic or Latino	3,196	97.14%
Population by Race		
White	890	27.05%
African American	2,250	68.39%
Asian	45	1.37%
American Indian and Alaska Native	6	0.18%
Native Hawaiian and Pacific Islander	1	0.03%
Other	20	0.61%
Identified by two or more	78	2.37%

Snow Hill, MD

Population by Sex/Age		
Male	966	45.93%
Female	1,137	54.07%
Under 18	487	23.16%
18 & over	1,616	76.84%
20 - 24	111	5.28%
25 - 34	188	8.94%
35 - 49	385	18.31%
50 - 64	451	21.45%
65 & over	425	20.21%
Population by Ethnicity		
Hispanic or Latino	34	1.62%
Non Hispanic or Latino	2,069	98.38%
Population by Race		
White	1,198	56.97%
African American	820	38.99%
Asian	28	1.33%
American Indian and Alaska Native	5	0.24%
Native Hawaiian and Pacific Islander	0	0.00%
Other	6	0.29%
Identified by two or more	46	2.19%

Salisbury, MD

Population by Sex/Age		
Male	14,043	46.28%
Female	16,300	53.72%
Under 18	6,588	21.71%
18 & over	23,755	78.29%
20 - 24	4,792	15.79%
25 - 34	4,479	14.76%
35 - 49	4,860	16.02%
50 - 64	4,122	13.58%
65 & over	3,371	11.11%
Population by Ethnicity		
Hispanic or Latino	2,128	7.01%
Non Hispanic or Latino	28,215	92.99%
Population by Race		
White	16,911	55.73%
African American	10,441	34.41%
Asian	964	3.18%
American Indian and Alaska Native	81	0.27%
Native Hawaiian and Pacific Islander	21	0.07%
Other	943	3.11%
Identified by two or more	982	3.24%

Pittsville, MD

Population by Sex/Age		
Male	675	47.64%
Female	742	52.36%
Under 18	331	23.36%
18 & over	1,086	76.64%
20 - 24	73	5.15%
25 - 34	190	13.41%
35 - 49	313	22.09%
50 - 64	294	20.75%
65 & over	179	12.63%
Population by Ethnicity		
Hispanic or Latino	27	1.91%
Non Hispanic or Latino	1,390	98.09%
Population by Race		
White	1,280	90.33%
African American	68	4.80%
Asian	22	1.55%
American Indian and Alaska Native	2	0.14%
Native Hawaiian and Pacific Islander	0	0.00%
Other	8	0.56%
Identified by two or more	37	2.61%

Berlin, MD

Population by Sex/Age		
Male	2,040	45.48%
Female	2,445	54.52%
Under 18	1,155	25.75%
18 & over	3,330	74.25%
20 - 24	252	5.62%
25 - 34	561	12.51%
35 - 49	869	19.38%
50 - 64	774	17.26%
65 & over	795	17.73%
Population by Ethnicity		
Hispanic or Latino	248	5.53%
Non Hispanic or Latino	4,237	94.47%
Population by Race		
White	3,085	68.78%
African American	1,045	23.30%
Asian	65	1.45%
American Indian and Alaska Native	25	0.56%
Native Hawaiian and Pacific Islander	0	0.00%
Other	119	2.65%
Identified by two or more	146	3.26%

Laurel, DE

Population by Sex/Age		
Male	1,689	45.55%
Female	2,019	54.45%
Under 18	1,229	33.14%
18 & over	2,479	66.86%
20 - 24	302	8.14%
25 - 34	476	12.84%
35 - 49	659	17.77%
50 - 64	507	13.67%
65 & over	390	10.52%
Population by Ethnicity		
Hispanic or Latino	329	8.87%
Non Hispanic or Latino	3,379	91.13%
Population by Race		
White	1,754	47.30%
African American	1,513	40.80%
Asian	34	0.92%
American Indian and Alaska Native	42	1.13%
Native Hawaiian and Pacific Islander	18	0.49%
Other	151	4.07%
Identified by two or more	196	5.29%

Millsboro, DE

Population by Sex/Age		
Male	1,702	43.90%
Female	2,175	56.10%
Under 18	840	21.67%
18 & over	3,037	78.33%
20 - 24	252	6.50%
25 - 34	563	14.52%
35 - 49	598	15.42%
50 - 64	716	18.47%
65 & over	812	20.94%
Population by Ethnicity		
Hispanic or Latino	252	6.50%
Non Hispanic or Latino	3,625	93.50%
Population by Race		
White	2,773	71.52%
African American	695	17.93%
Asian	129	3.33%
American Indian and Alaska Native	20	0.52%
Native Hawaiian and Pacific Islander	0	0.00%
Other	131	3.38%
Identified by two or more	129	3.33%

Ocean View, DE

Population by Sex/Age		
Male	881	46.81%
Female	1,001	53.19%
Under 18	238	12.65%
18 & over	1,644	87.35%
20 - 24	50	2.66%
25 - 34	105	5.58%
35 - 49	278	14.77%
50 - 64	540	28.69%
65 & over	647	34.38%
Population by Ethnicity		
Hispanic or Latino	51	2.71%
Non Hispanic or Latino	1,831	97.29%
Population by Race		
White	1,818	96.60%
African American	16	0.85%
Asian	24	1.28%
American Indian and Alaska Native	1	0.05%
Native Hawaiian and Pacific Islander	0	0.00%
Other	5	0.27%
Identified by two or more	18	0.96%

Georgetown, DE

Population by Sex/Age		
Male	3,232	50.33%
Female	3,190	49.67%
Under 18	1,872	29.15%
18 & over	4,550	70.85%
20 - 24	623	9.70%
25 - 34	1,152	17.94%
35 - 49	1,024	15.95%
50 - 64	796	12.39%
65 & over	786	12.24%
Population by Ethnicity		
Hispanic or Latino	3,067	47.76%
Non Hispanic or Latino	3,355	52.24%
Population by Race		
White	2,991	46.57%
African American	933	14.53%
Asian	70	1.09%
American Indian and Alaska Native	277	4.31%
Native Hawaiian and Pacific Islander	9	0.14%
Other	1,905	29.66%
Identified by two or more	237	3.69%

Milton, DE

Population by Sex/Age		
Male	1,198	46.51%
Female	1,378	53.49%
Under 18	550	21.35%
18 & over	2,026	78.65%
20 - 24	151	5.86%
25 - 34	376	14.60%
35 - 49	489	18.98%
50 - 64	519	20.15%
65 & over	437	16.96%
Population by Ethnicity		
Hispanic or Latino	241	9.36%
Non Hispanic or Latino	2,335	90.64%
Population by Race		
White	1,952	75.78%
African American	421	16.34%
Asian	15	0.58%
American Indian and Alaska Native	18	0.70%
Native Hawaiian and Pacific Islander	1	0.04%
Other	80	3.11%
Identified by two or more	89	3.45%

Lewes, DE

Population by Sex/Age		
Male	1,222	44.48%
Female	1,525	55.52%
Under 18	257	9.36%
18 & over	2,490	90.64%
20 - 24	60	2.18%
25 - 34	141	5.13%
35 - 49	310	11.29%
50 - 64	754	27.45%
65 & over	1,199	43.65%
Population by Ethnicity		
Hispanic or Latino	48	1.75%
Non Hispanic or Latino	2,699	98.25%
Population by Race		
White	2,468	89.84%
African American	211	7.68%
Asian	10	0.36%
American Indian and Alaska Native	10	0.36%
Native Hawaiian and Pacific Islander	2	0.07%
Other	9	0.33%
Identified by two or more	37	1.35%

n/a

A.6 Hot-Dry Region – Southern CA

Ventura

Population by Sex/Age		
Male	52,592	49.41%
Female	53,841	50.59%
Under 18	23,918	22.47%
18 & over	82,515	77.53%
20 - 24	6,677	6.27%
25 - 34	14,248	13.39%
35 - 49	22,906	21.52%
50 - 64	21,617	20.31%
65 & over	14,163	13.31%
Population by Ethnicity		
Hispanic or Latino	33,874	31.83%
Non Hispanic or Latino	72,559	68.17%
Population by Race		
White	81,553	76.62%
African American	1,724	1.62%
Asian	3,663	3.44%
American Indian and Alaska Native	1,287	1.21%
Native Hawaiian and Pacific Islander	206	0.19%
Other	12,486	11.73%
Identified by two or more	5,514	5.18%

Oxnard

Population by Sex/Age		
Male	100,389	50.73%
Female	97,510	49.27%
Under 18	59,018	29.82%
18 & over	138,881	70.18%
20 - 24	16,993	8.59%
25 - 34	31,237	15.78%
35 - 49	39,055	19.73%
50 - 64	28,258	14.28%
65 & over	16,418	8.30%
Population by Ethnicity		
Hispanic or Latino	145,551	73.55%
Non Hispanic or Latino	52,348	26.45%
Population by Race		
White	95,346	48.18%
African American	5,771	2.92%
Asian	14,550	7.35%
American Indian and Alaska Native	2,953	1.49%
Native Hawaiian and Pacific Islander	658	0.33%
Other	69,527	35.13%
Identified by two or more	9,094	4.60%

Santa Paula

Population by Sex/Age		
Male	14,795	50.46%
Female	14,526	49.54%
Under 18	8,722	29.75%
18 & over	20,599	70.25%
20 - 24	2,278	7.77%
25 - 34	4,182	14.26%
35 - 49	5,635	19.22%
50 - 64	4,388	14.97%
65 & over	3,099	10.57%
Population by Ethnicity		
Hispanic or Latino	23,299	79.46%
Non Hispanic or Latino	6,022	20.54%
Population by Race		
White	18,458	62.95%
African American	152	0.52%
Asian	216	0.74%
American Indian and Alaska Native	460	1.57%
Native Hawaiian and Pacific Islander	24	0.08%
Other	8,924	30.44%
Identified by two or more	1,087	3.71%

Camarillo

Population by Sex/Age		
Male	31,535	48.37%
Female	33,666	51.63%
Under 18	15,115	23.18%
18 & over	50,086	76.82%
20 - 24	3,667	5.62%
25 - 34	7,531	11.55%
35 - 49	13,335	20.45%
50 - 64	12,854	19.71%
65 & over	11,202	17.18%
Population by Ethnicity		
Hispanic or Latino	14,958	22.94%
Non Hispanic or Latino	50,243	77.06%
Population by Race		
White	48,947	75.07%
African American	1,216	1.87%
Asian	6,633	10.17%
American Indian and Alaska Native	397	0.61%
Native Hawaiian and Pacific Islander	116	0.18%
Other	4,774	7.32%
Identified by two or more	3,118	4.78%

Piru

Population by Sex/Age		
Male	1,064	51.58%
Female	999	48.42%
Under 18	676	32.77%
18 & over	1,387	67.23%
20 - 24	170	8.24%
25 - 34	286	13.86%
35 - 49	400	19.39%
50 - 64	303	14.69%
65 & over	155	7.51%
Population by Ethnicity		
Hispanic or Latino	1,748	84.73%
Non Hispanic or Latino	315	15.27%
Population by Race		
White	1,063	51.53%
African American	16	0.78%
Asian	11	0.53%
American Indian and Alaska Native	43	2.08%
Native Hawaiian and Pacific Islander	0	0.00%
Other	830	40.23%
Identified by two or more	100	4.85%

Simi Valley

Population by Sex/Age		
Male	61,043	49.13%
Female	63,194	50.87%
Under 18	31,036	24.98%
18 & over	93,201	75.02%
20 - 24	7,536	6.07%
25 - 34	15,355	12.36%
35 - 49	29,110	23.43%
50 - 64	24,471	19.70%
65 & over	13,177	10.61%
Population by Ethnicity		
Hispanic or Latino	28,938	23.29%
Non Hispanic or Latino	95,299	76.71%
Population by Race		
White	93,597	75.34%
African American	1,739	1.40%
Asian	11,555	9.30%
American Indian and Alaska Native	761	0.61%
Native Hawaiian and Pacific Islander	178	0.14%
Other	10,685	8.60%
Identified by two or more	5,722	4.61%

Thousand Oaks

Population by Sex/Age		
Male	61,989	48.93%
Female	64,694	51.07%
Under 18	30,076	23.74%
18 & over	96,607	76.26%
20 - 24	6,803	5.37%
25 - 34	12,447	9.83%
35 - 49	28,479	22.48%
50 - 64	26,891	21.23%
65 & over	18,564	14.65%
Population by Ethnicity		
Hispanic or Latino	21,341	16.85%
Non Hispanic or Latino	105,342	83.15%
Population by Race		
White	101,702	80.28%
African American	1,674	1.32%
Asian	11,043	8.72%
American Indian and Alaska Native	497	0.39%
Native Hawaiian and Pacific Islander	146	0.12%
Other	6,869	5.42%
Identified by two or more	4,752	3.75%

Castaic

Population by Sex/Age		
Male	9,566	50.31%
Female	9,449	49.69%
Under 18	5,761	30.30%
18 & over	13,254	69.70%
20 - 24	1,064	5.60%
25 - 34	1,866	9.81%
35 - 49	5,138	27.02%
50 - 64	3,442	18.10%
65 & over	1,091	5.74%
Population by Ethnicity		
Hispanic or Latino	4,716	24.80%
Non Hispanic or Latino	14,299	75.20%
Population by Race		
White	13,607	71.56%
African American	630	3.31%
Asian	2,162	11.37%
American Indian and Alaska Native	119	0.63%
Native Hawaiian and Pacific Islander	26	0.14%
Other	1,466	7.71%
Identified by two or more	1,005	5.29%

Santa Clarita

Population by Sex/Age		
Male	86,884	49.28%
Female	89,436	50.72%
Under 18	46,180	26.19%
18 & over	130,140	73.81%
20 - 24	12,052	6.84%
25 - 34	21,601	12.25%
35 - 49	41,168	23.35%
50 - 64	32,955	18.69%
65 & over	16,851	9.56%
Population by Ethnicity		
Hispanic or Latino	51,941	29.46%
Non Hispanic or Latino	124,379	70.54%
Population by Race		
White	125,005	70.90%
African American	5,623	3.19%
Asian	15,025	8.52%
American Indian and Alaska Native	1,013	0.57%
Native Hawaiian and Pacific Islander	272	0.15%
Other	21,169	12.01%
Identified by two or more	8,213	4.66%

Los Angeles, Northridge neighborhood

Population by Sex/Age		
Male	1,889,064	49.81%
Female	1,903,557	50.19%
Under 18	874,525	23.06%
18 & over	2,918,096	76.94%
20 - 24	314,543	8.29%
25 - 34	638,900	16.85%
35 - 49	831,705	21.93%
50 - 64	616,317	16.25%
65 & over	396,696	10.46%
Population by Ethnicity		
Hispanic or Latino	1,838,822	48.48%
Non Hispanic or Latino	1,953,799	51.52%
Population by Race		
White	1,888,158	49.79%
African American	365,118	9.63%
Asian	426,959	11.26%
American Indian and Alaska Native	28,215	0.74%
Native Hawaiian and Pacific Islander	5,577	0.15%
Other	902,959	23.81%
Identified by two or more	175,635	4.63%

B. Appendix - Meteorological Assessment

A preliminary examination of meteorological effects on sonic boom footprints for the F-18 low-boom dive maneuver was conducted in order to understand the potential changes in footprints (placement, magnitude, area, focal zones). This is important for the assessment of test risks but is also key in the development of meteorological criteria for a potential Phase 2 F-18 Dive dose-response test. The Meteorological criteria will be used to aid the site selection process and also as daily go/no-go criteria during test execution. The guidelines will be used to assess percentage of time meteorological conditions are met at sites under consideration. For this assessment, flight operations from the candidate Ellington Field Joint Reserve Base and participants in the Houston Texas area were examined with a single F-18 nominal dive trajectory (Figure B-1). The trajectory was not adapted due to changes in upper air conditions. Historical data from the Integrated Global Radiosonde Archive Weather Stations was examined for 1971 through 2016. For months under consideration for the Phase 2 test, the upper air data has been plotted (January, Figure B-2; February Figure B-3; March, Figure B-4).

The meteorological data used in the F-18 Dive Boom Propagation analysis is as follows:

- 72240 LCH Lake Charles Observations, Longitude = -93.22, Latitude = 30.12, Elevation = 32.81 ft
- Data obtained from http://weather.uwyo.edu/upperair/sounding.html
- Jan, Feb, Mar 2015 Analysis (Dates: 01, 05, 10, 15, 20, 25, 30)
- Sounding times: Zulu 0000 (5 pm, local) and Zulu 1200 (5 am, local)

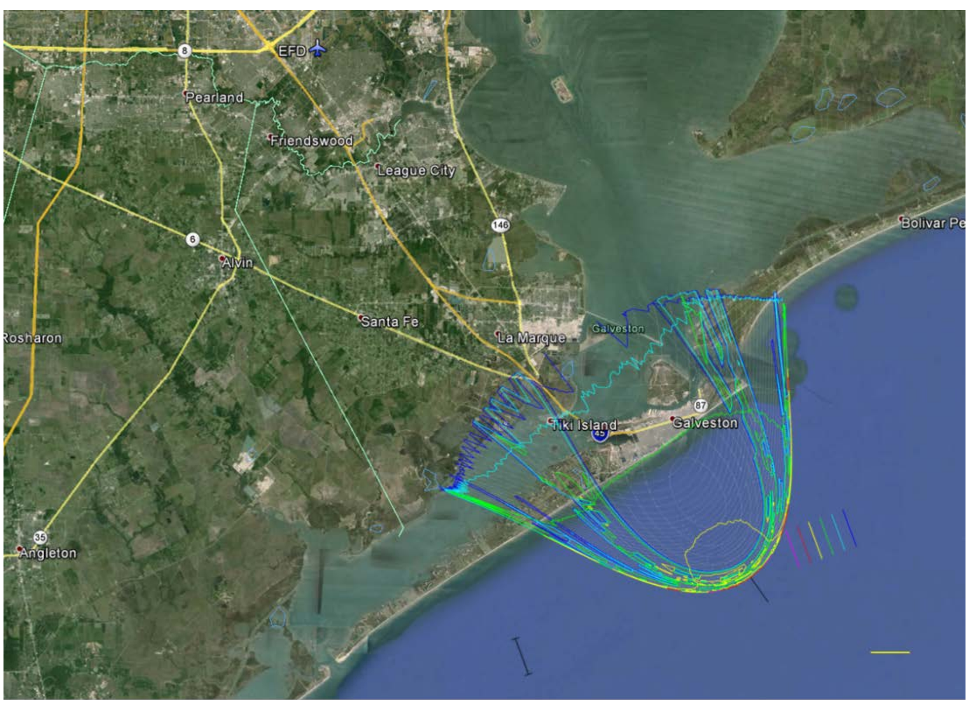


Figure B-1 Low Boom Dive Nominal Footprint (US Standard Atmosphere, no winds), Galveston Texas

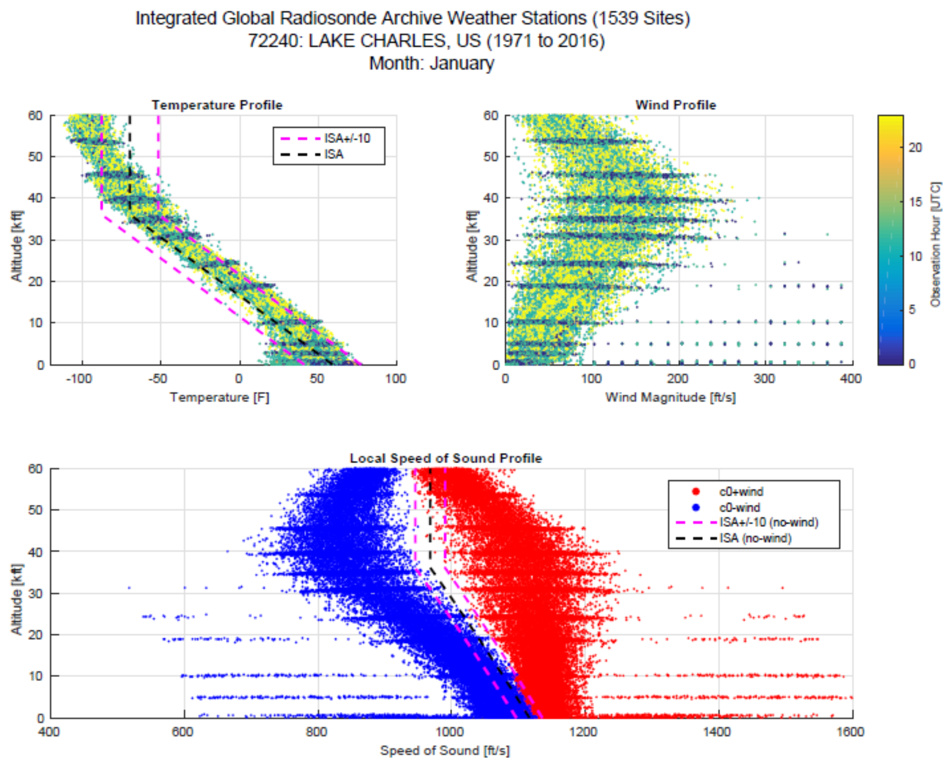


Figure B-2 Lake Charles January Upper Air Data (1971 – 2016)

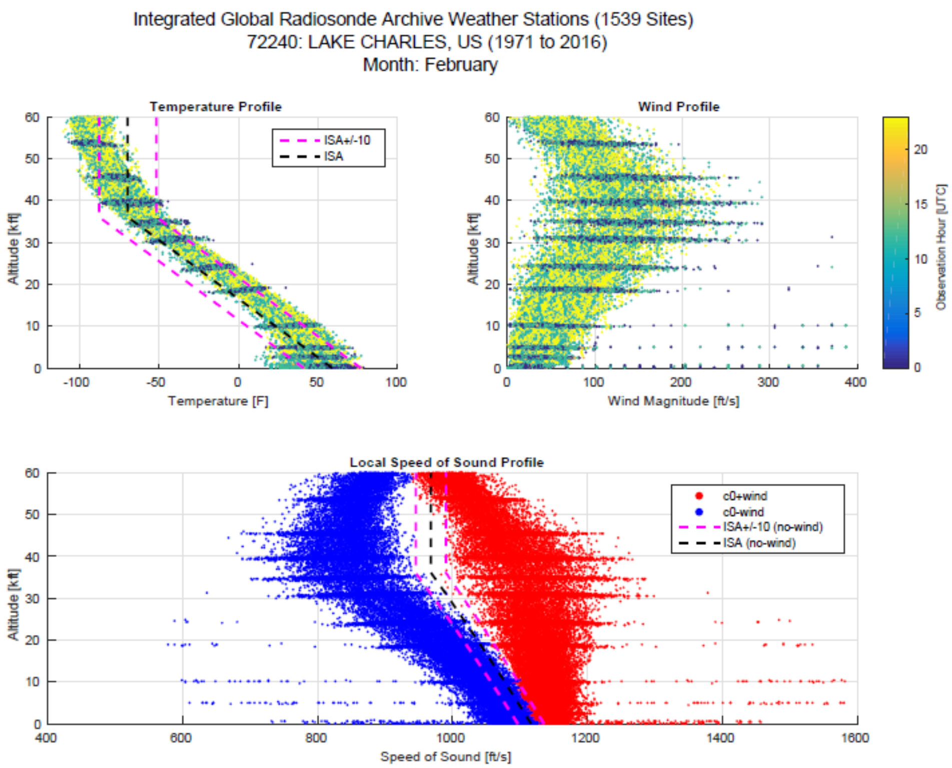


Figure B-3 Lake Charles February Upper Air Data (1971 – 2016)

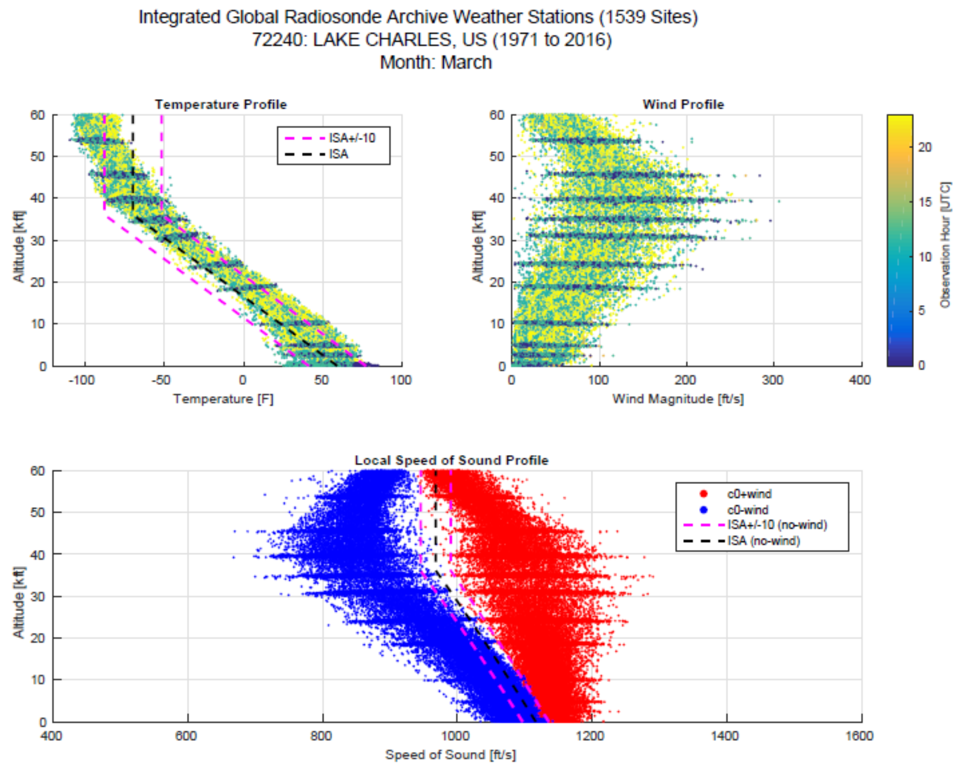


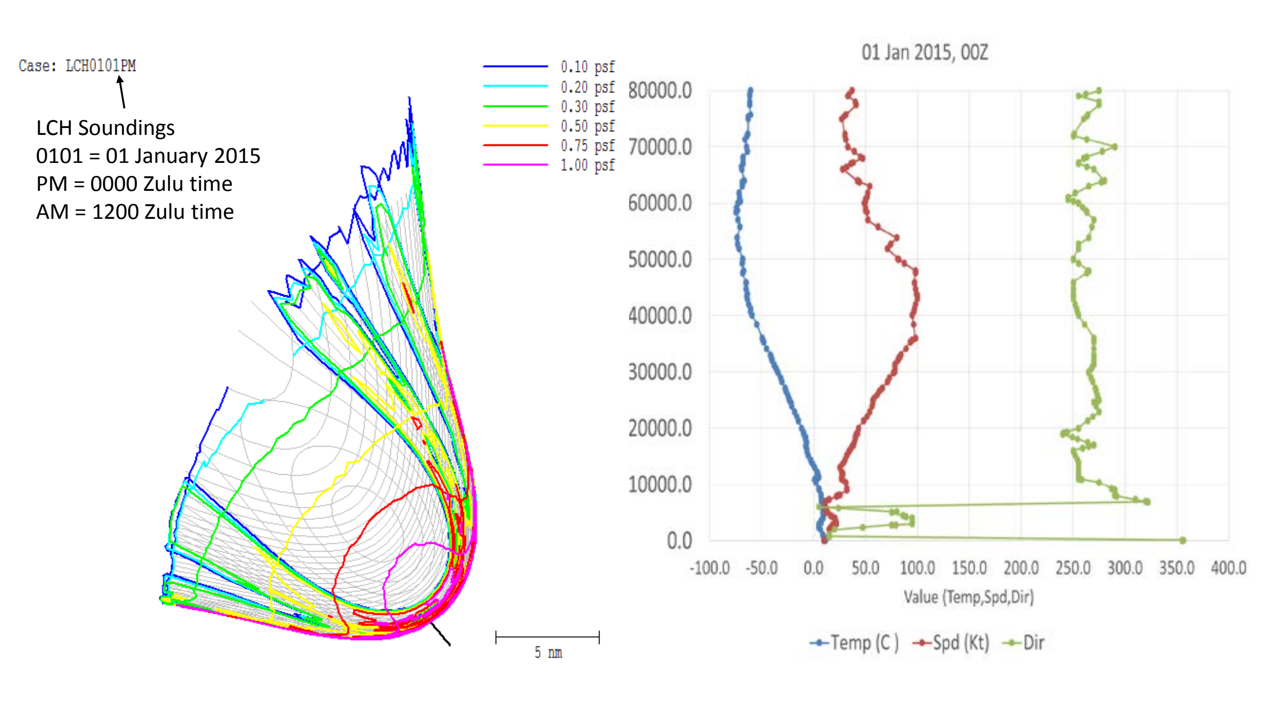
Figure B-4 Lake Charles March Upper Air Data (1971-2016)

Potential Meteorological Criteria could include metrics regarding the following items:

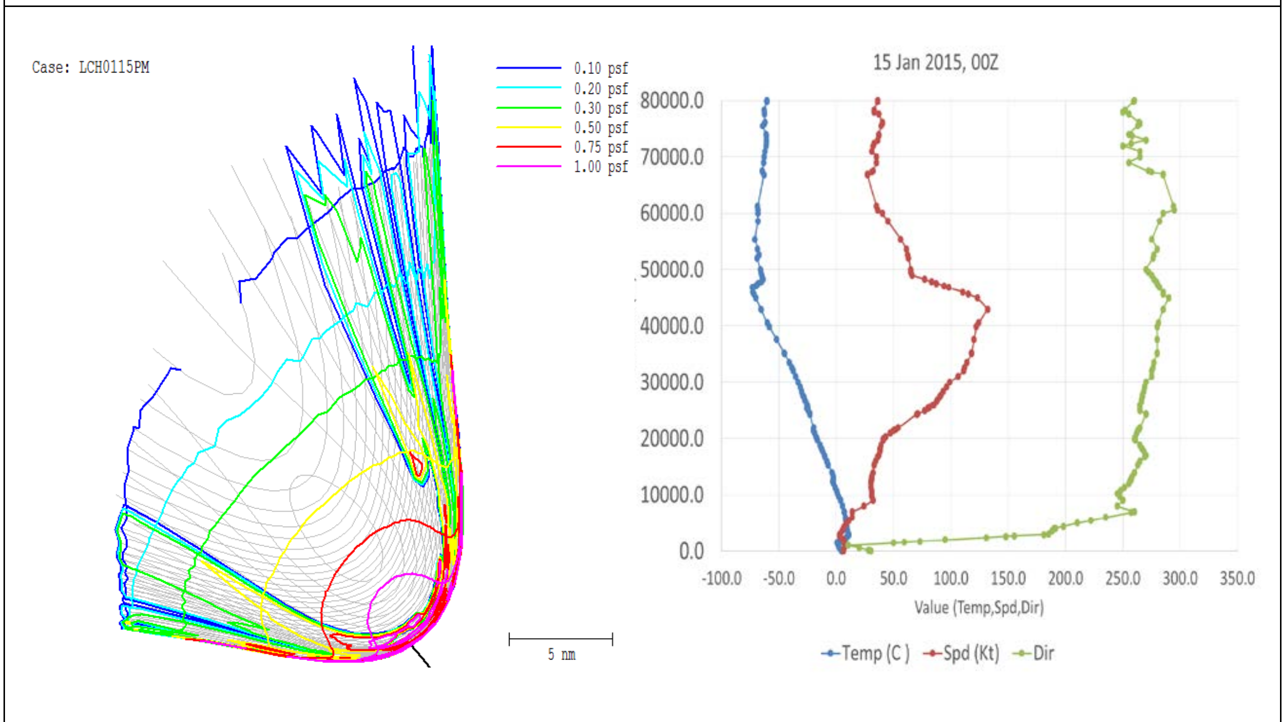
- Wind (Cross wind vs. Downwind vs. Upwind) prevalence
    - Methodical examination of wind effects on F18 Dive Footprints
    - Identify and determine acceptable wind magnitude / direction / altitude bands
- Size of higher amplitude (>.75 psf) and lower amplitude (<.3 psf) boom footprint areas
    - Leverage WSPR 2011 data. *Is WSPR trajectory & Upper Air data available from NASA?*
    - Develop relationship between measured Metrics (PLdB) and PCBoom levels
- Humidity Effects on Loudness Levels
    - Assess humidity change metric effects between EAFB and other sites
    - Potential for NASA conducting an F-18 Dive at a high humidity SonicBAT location?
- Size (length) of focal zone along the leading edge of the footprint crescent
- Lowest boom overpressure level achievable – Include reality of low-booms beyond PCBoom predicted cutoff

In order to assess any additional risks execution of the F-18 Low Boom Dive maneuver might introduce in terms of footprint changes due to local atmospheric influences, a set of PCBoom footprints were generated using selected morning and evening upper air data for January, February and March 2015. The legacy flat-earth model in PCBoom was employed. In the remainder of this appendix, this series of PCBoom footprints are displayed along with the corresponding upper air temperature, wind speed and wind direction. The intent of these is to familiarize the reader with the variability in the range of footprint area coverage, focal zone extent, overpressure values, cleanliness and shape of the footprints, shape and size of the contour areas and the like. At this point we have not conducted a systematic examination of the effect of upper air wind and temperature profiles on the footprints, so no concluding observations will be drawn.

In phase 2, if awarded, to the greatest extent possible, we will leverage the WSPR 2011 and other F-18 Low Boom dive data and NASA's F-18 Dive PCBoom (WSPR) waypoint development process and experience. There are a number of parameters available within PCBoom which control the ray tube propagation. These need to be examined in more detail in the PCBoom analysis. It is also possible to utilize PCBoom with non-flat terrain to more accurately calculate where cutoff occurs due to rays refracting upwards. These could be examined in more detail by using site-specific terrain in the PCBoom analysis. The footprints may also be georeferenced and overlaid on maps. During Phase 2, it may be necessary to develop some empirical loudness relationships between PCBoom footprints (psf) and loudness levels (PLdB) and incorporate them into the footprint prediction process for use in both the test design and day-of-flight waypoint calculations.



01 Jan 2015 0000 Zulu (5 PM Local) PCBoom Footprint and Meteorological Upper Air Sounding Data



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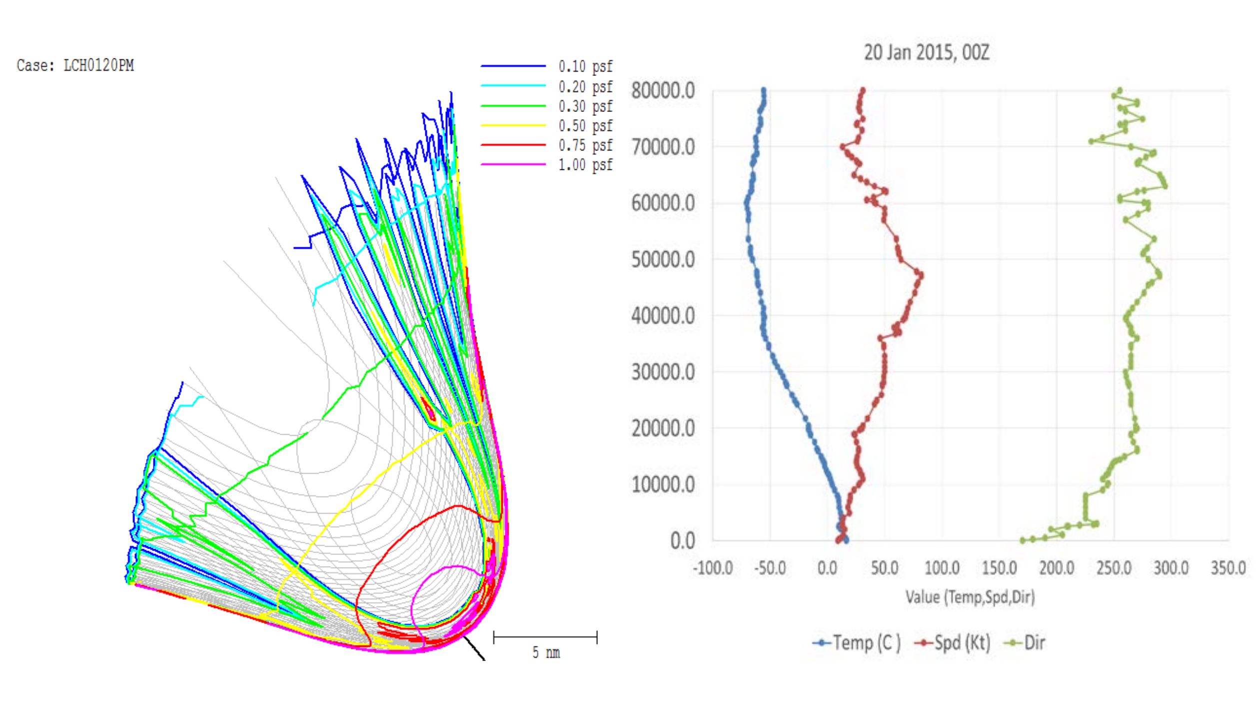

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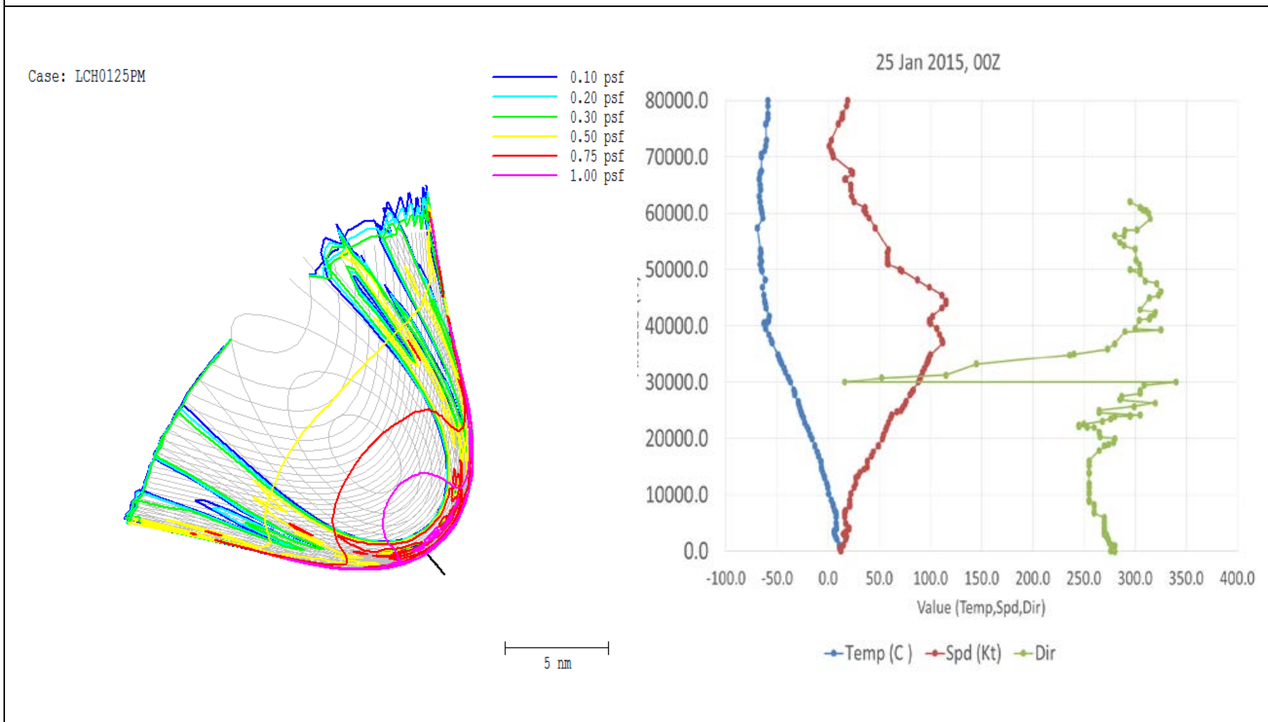

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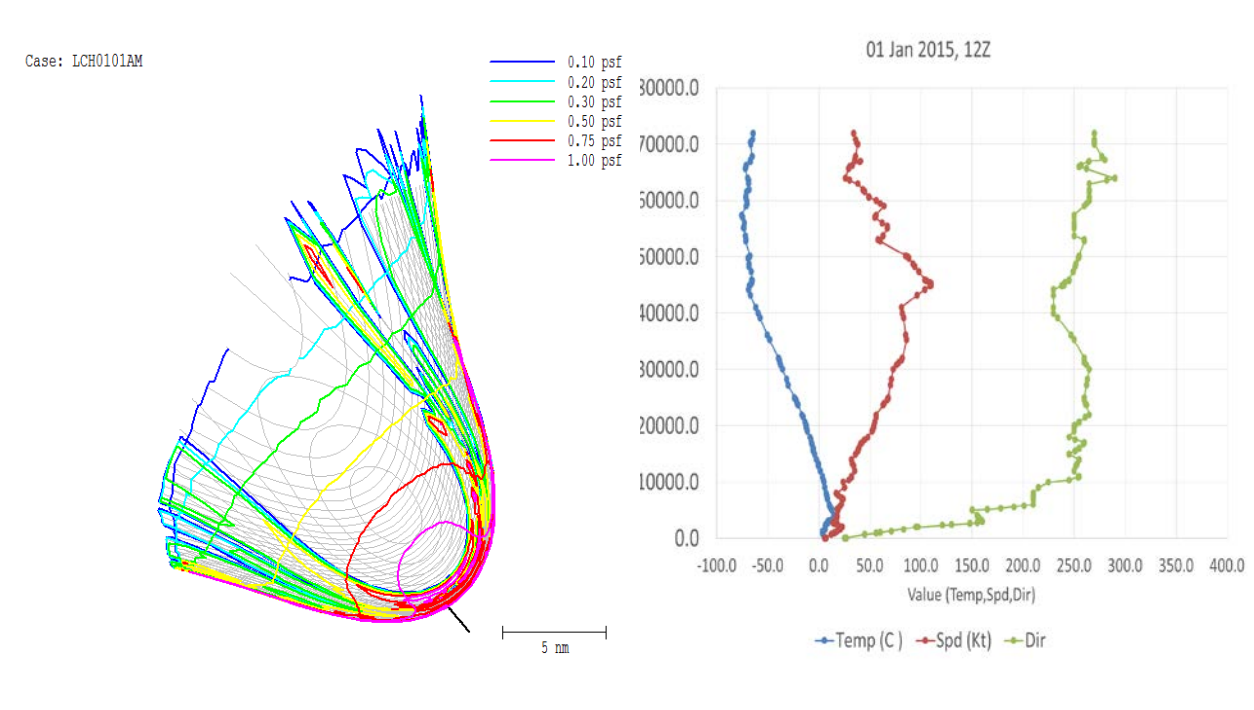

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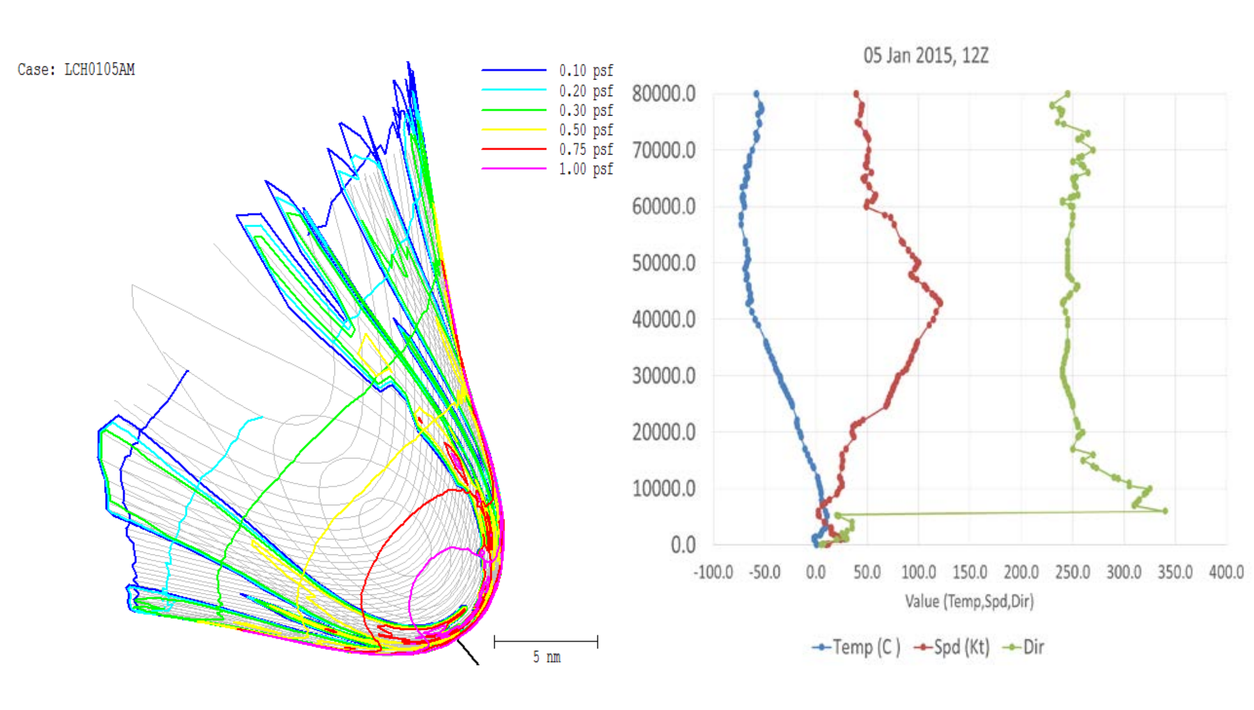

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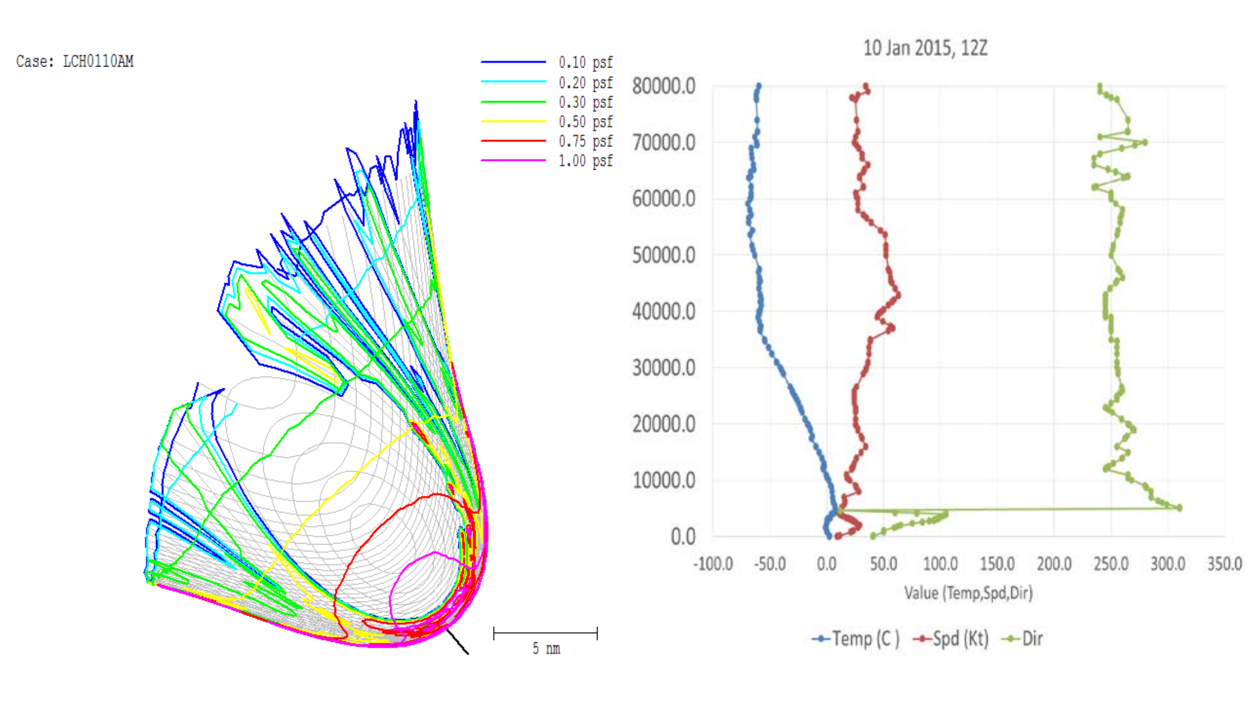

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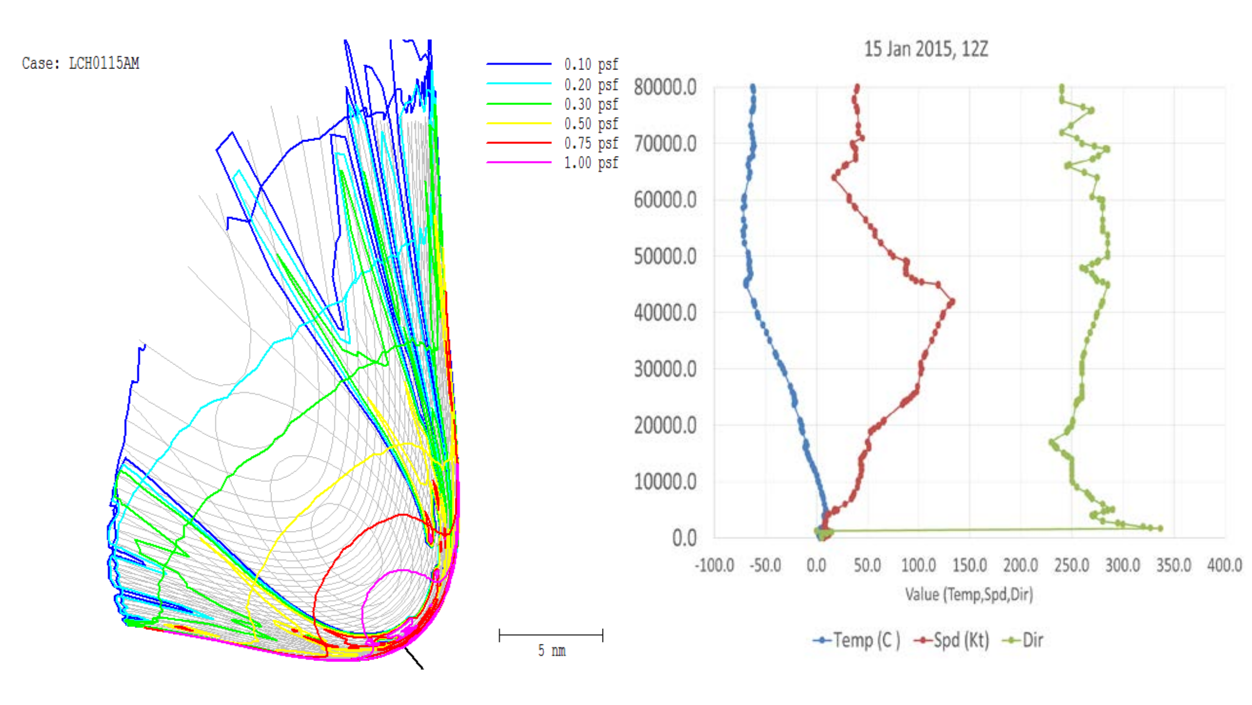

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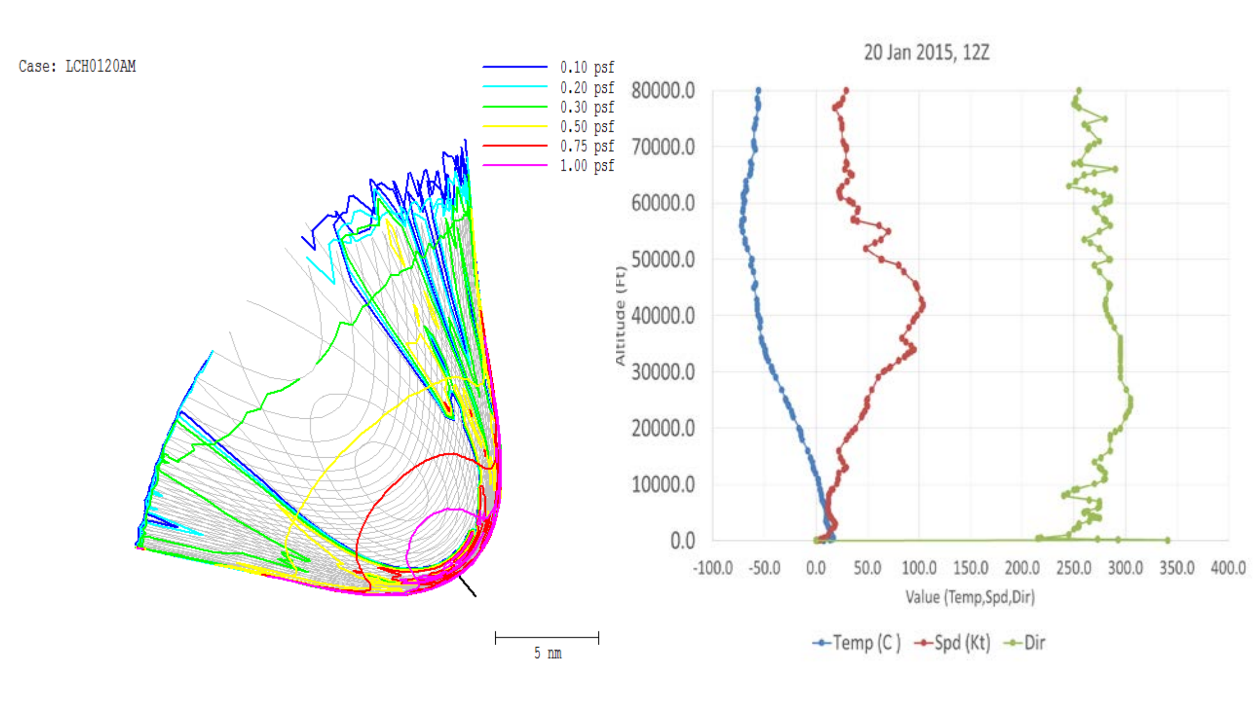

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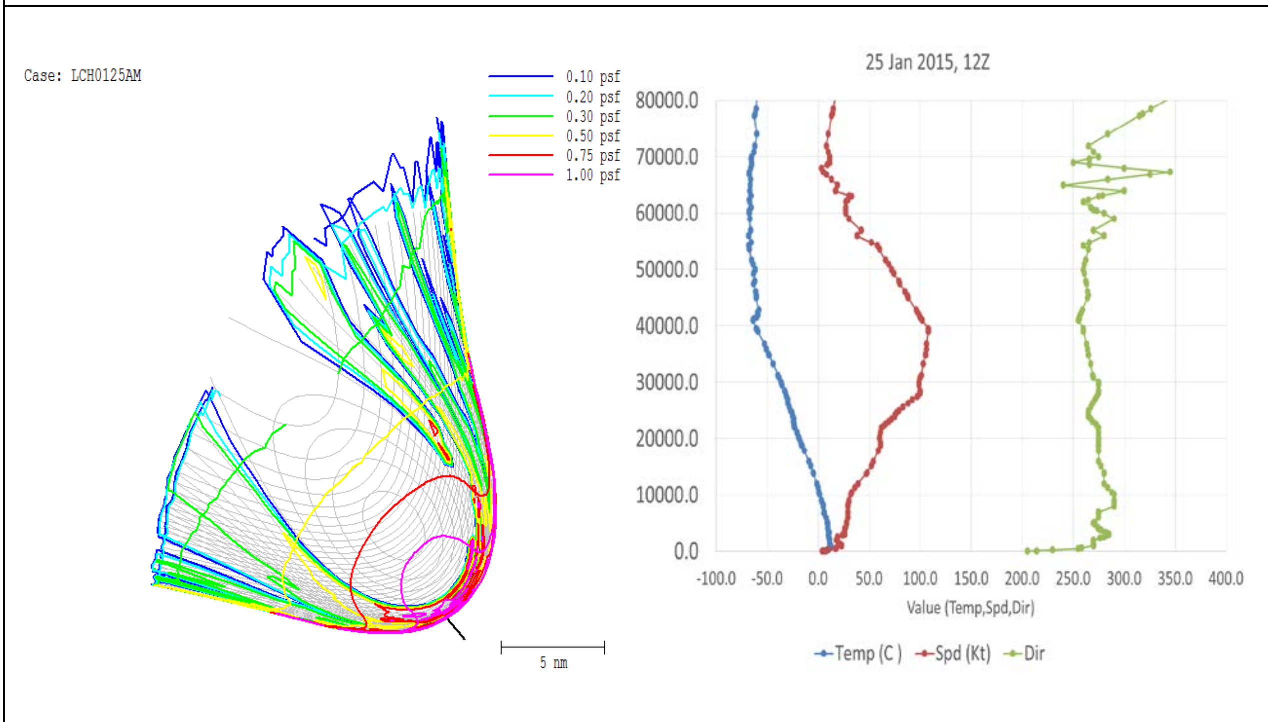

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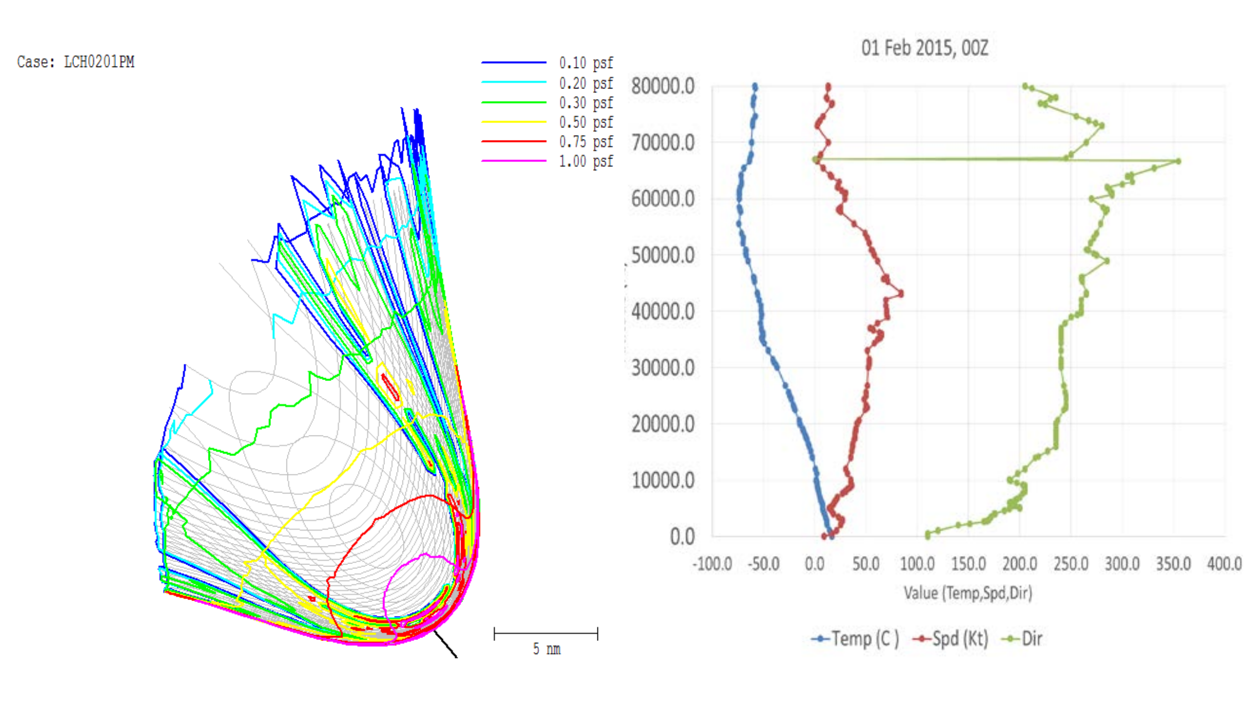

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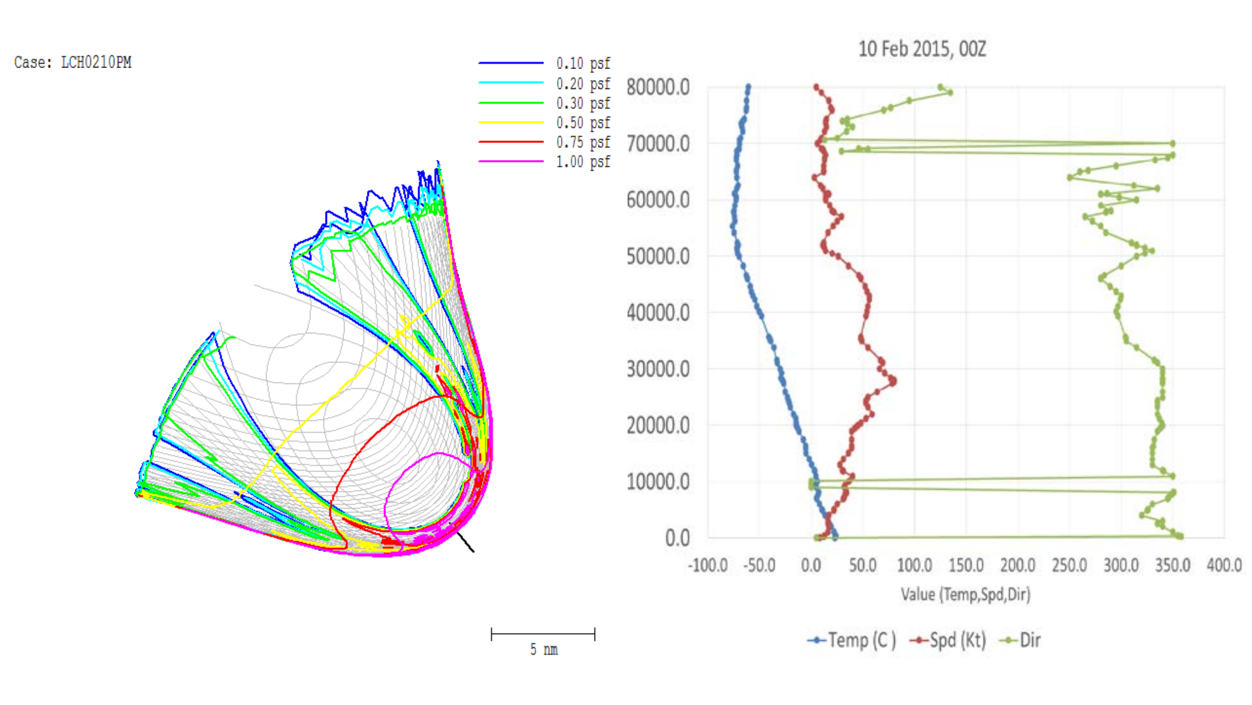

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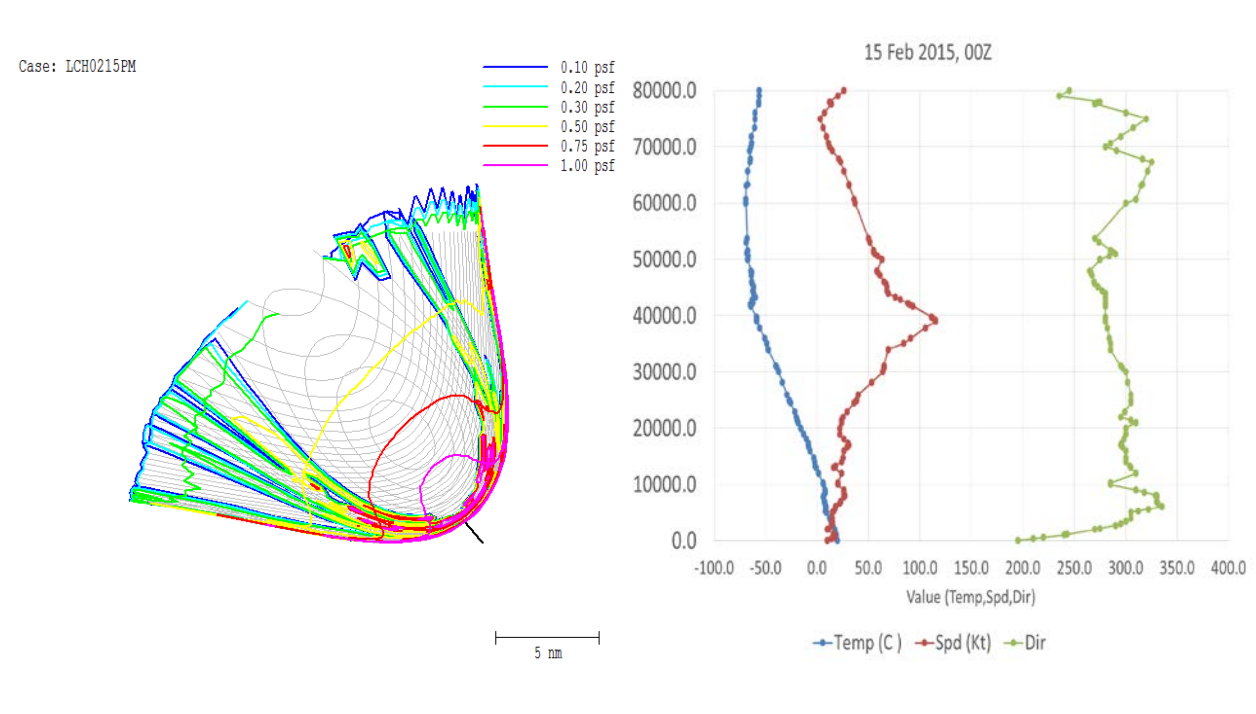

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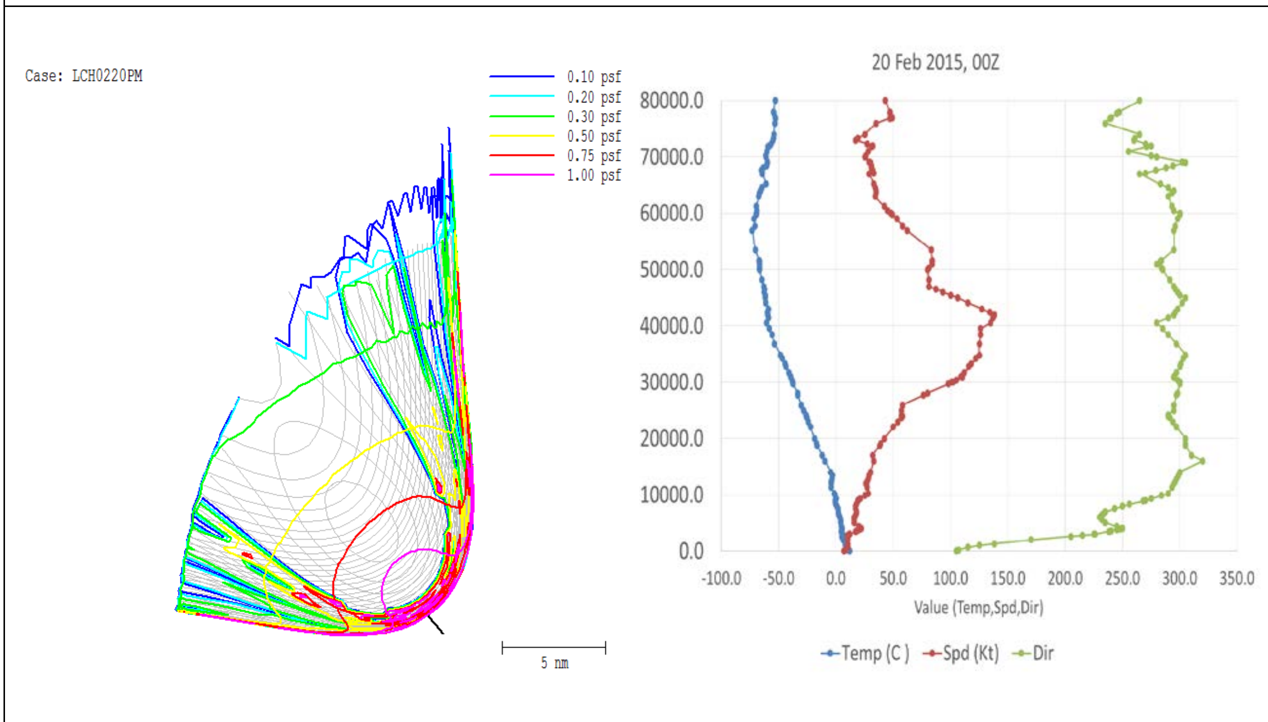

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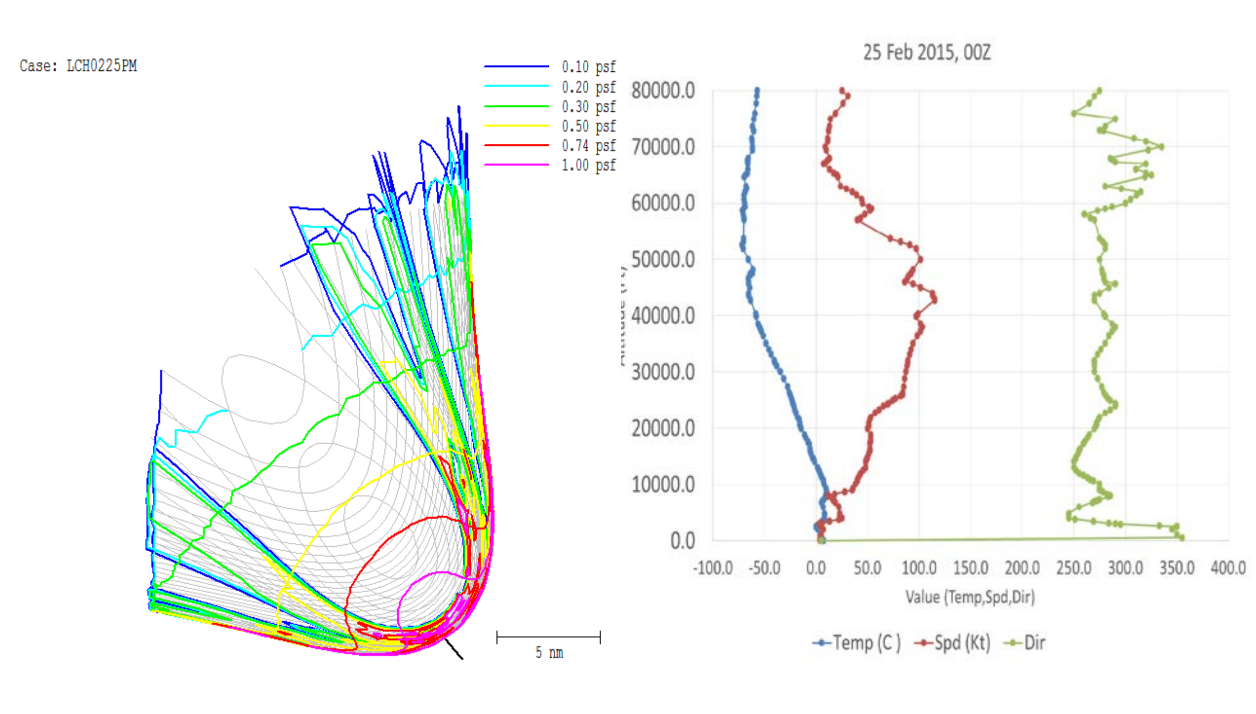

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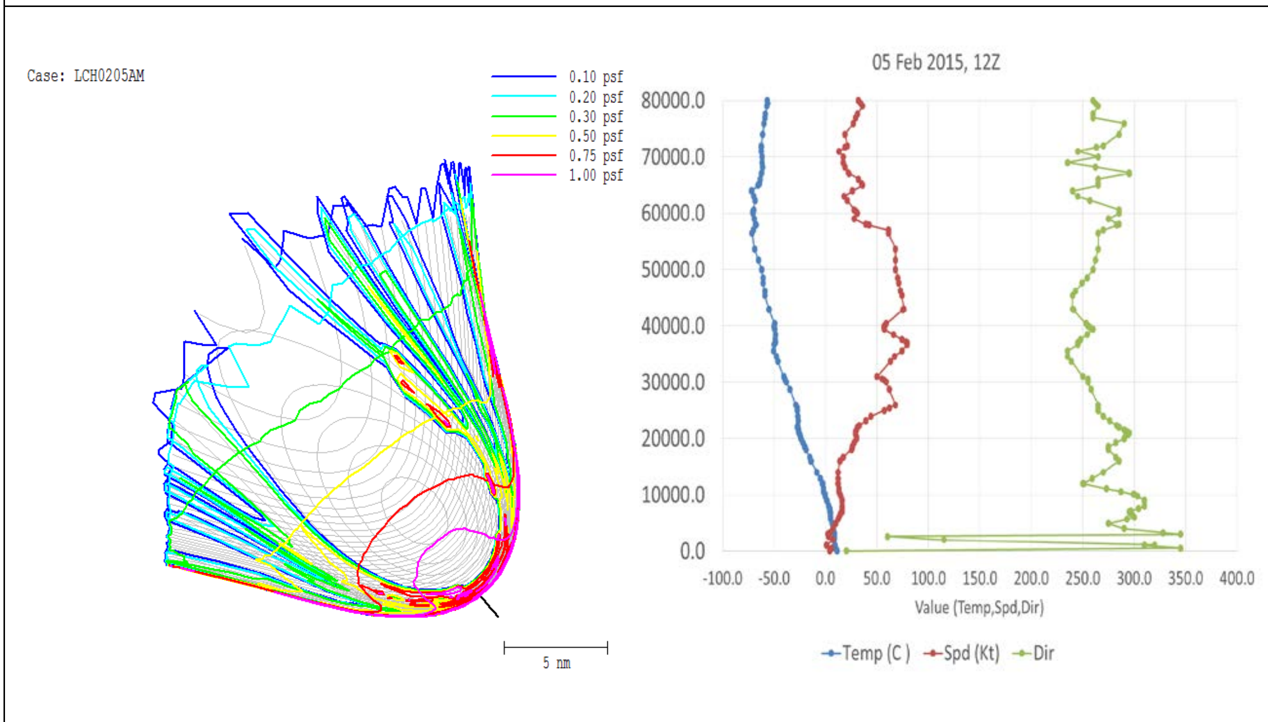

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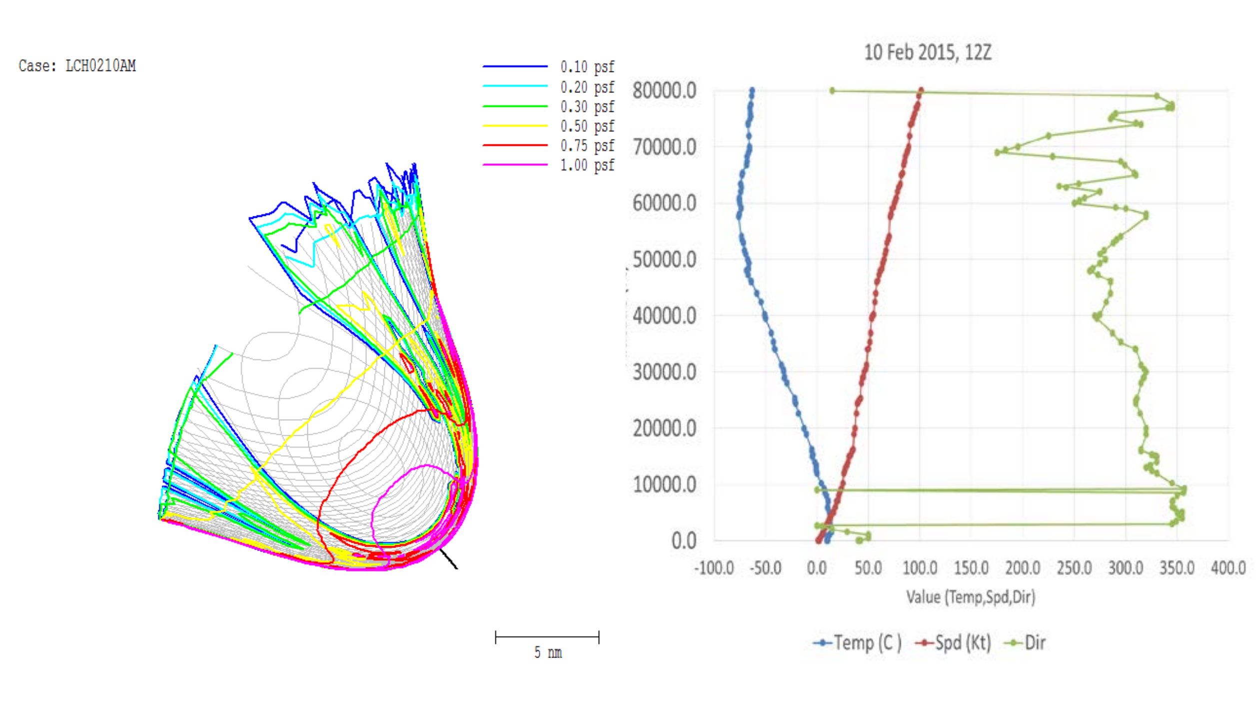

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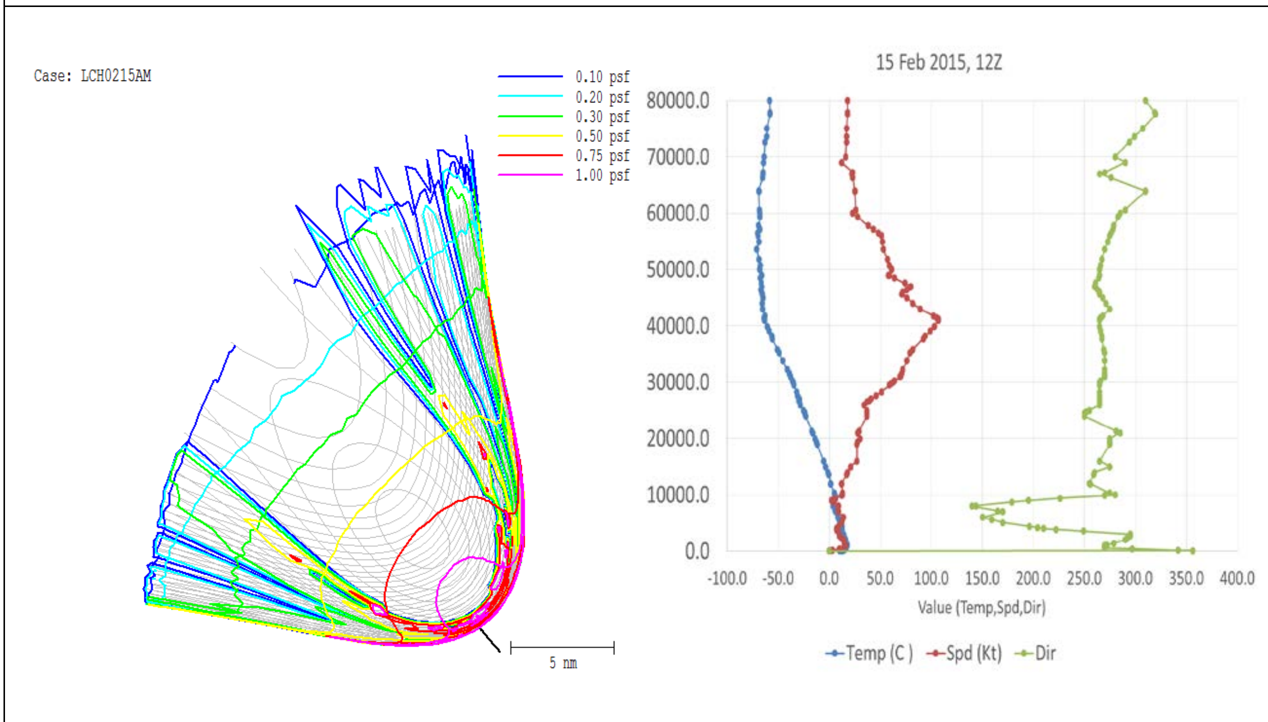

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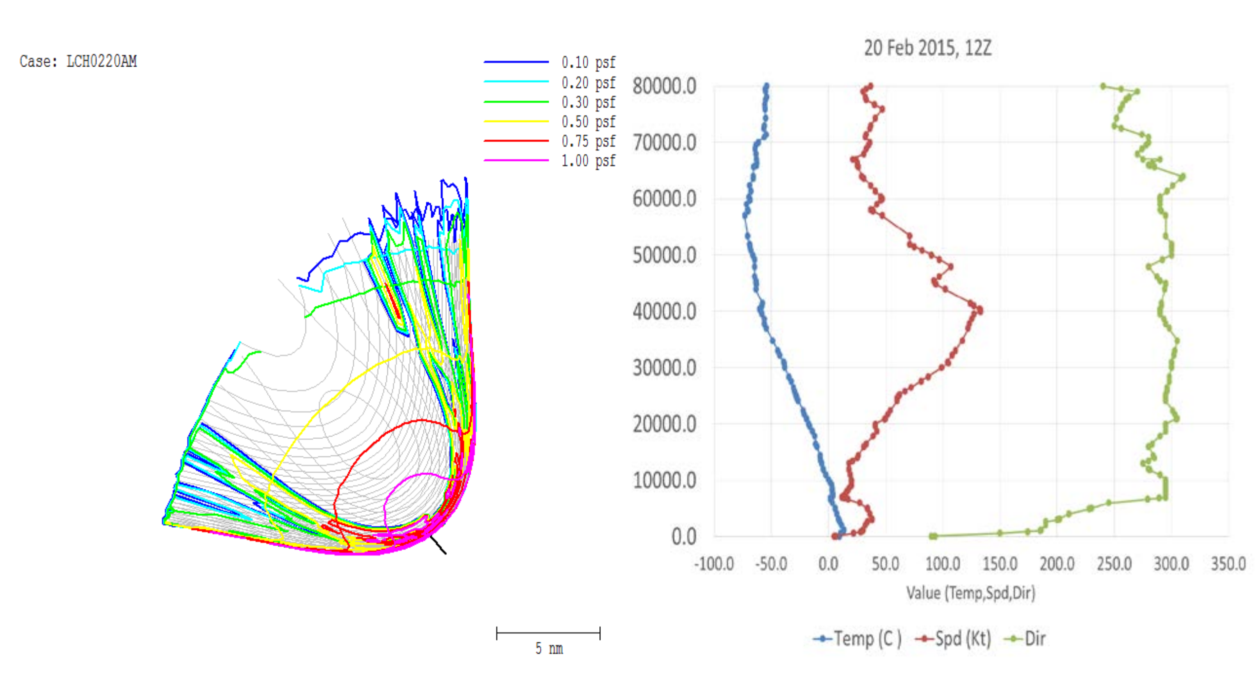

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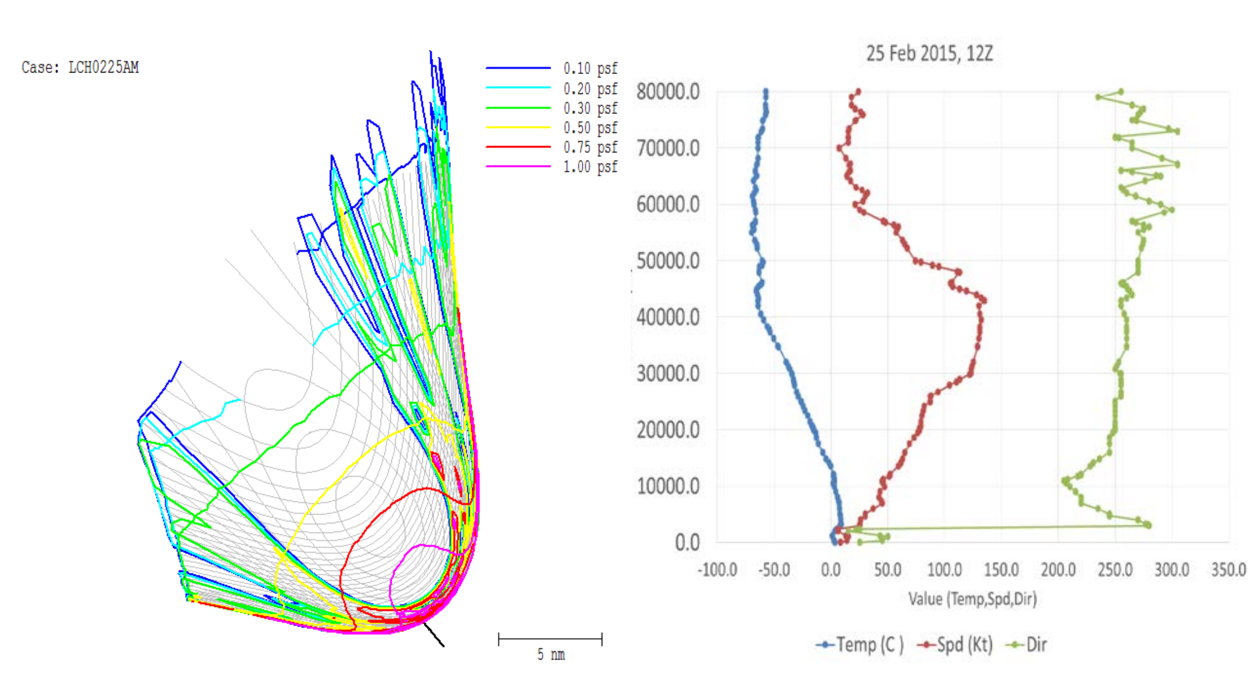

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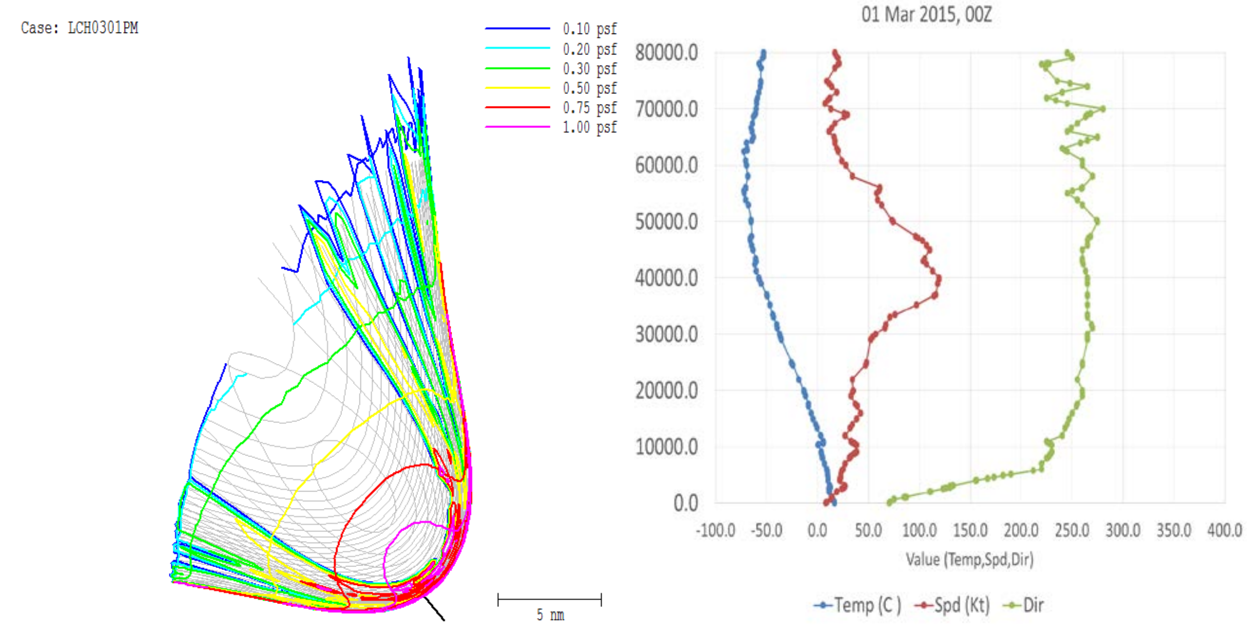

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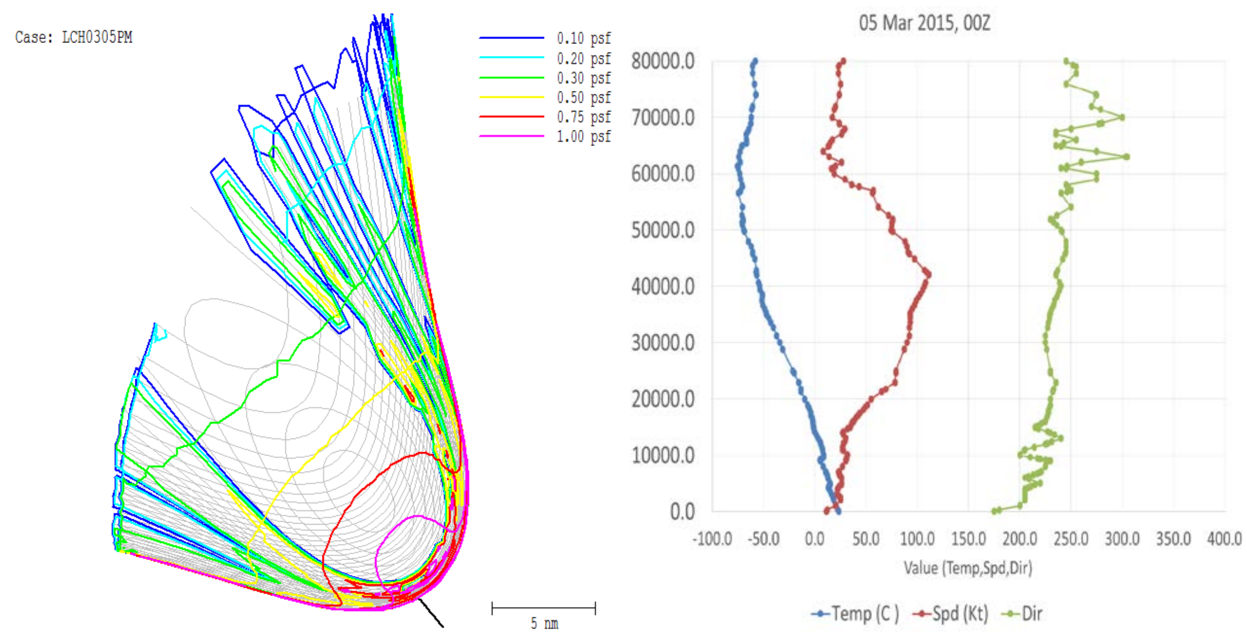

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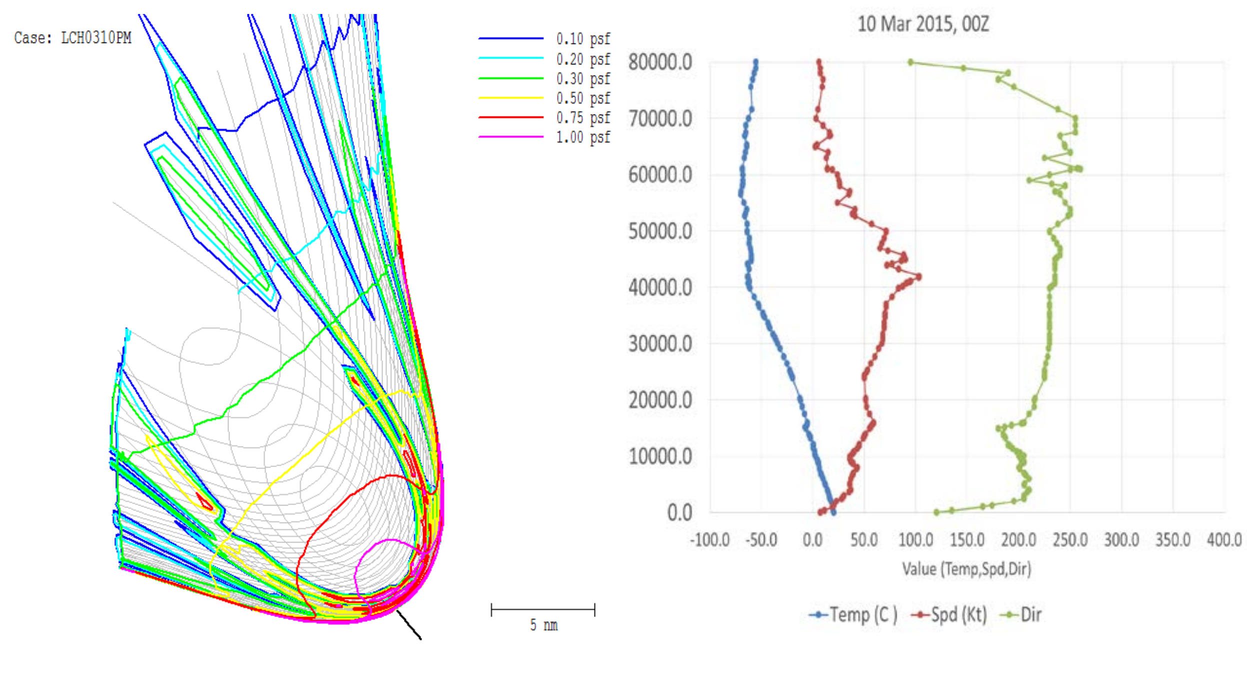

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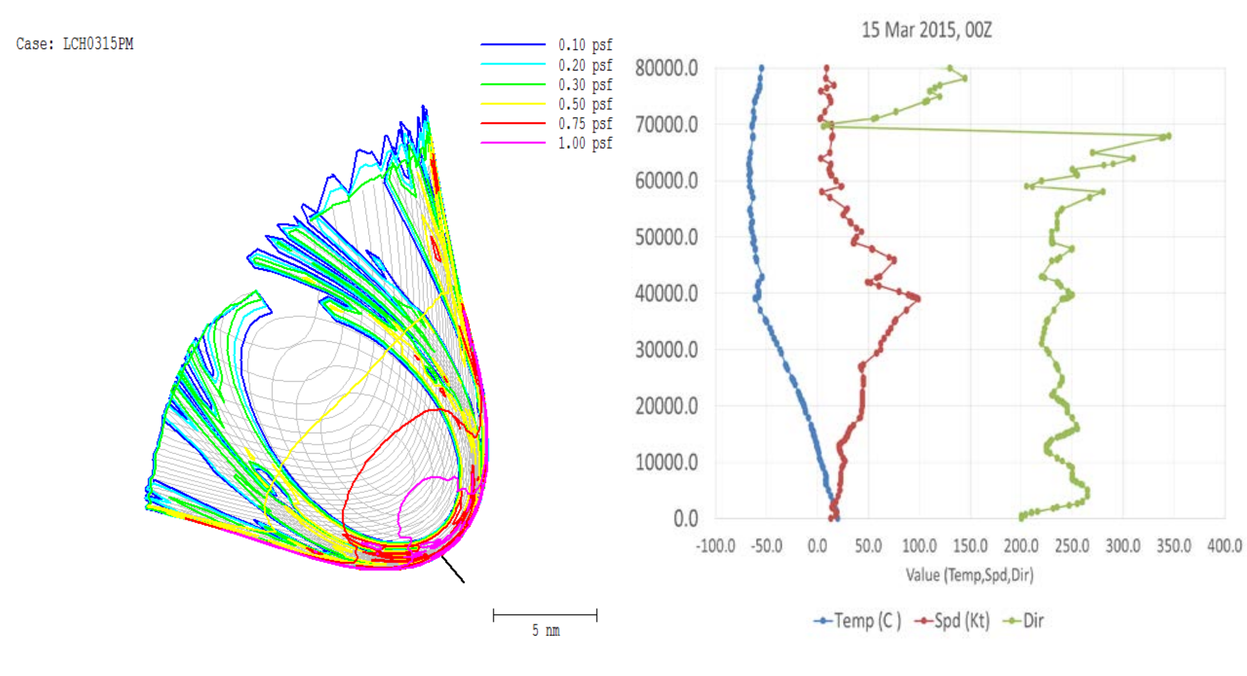

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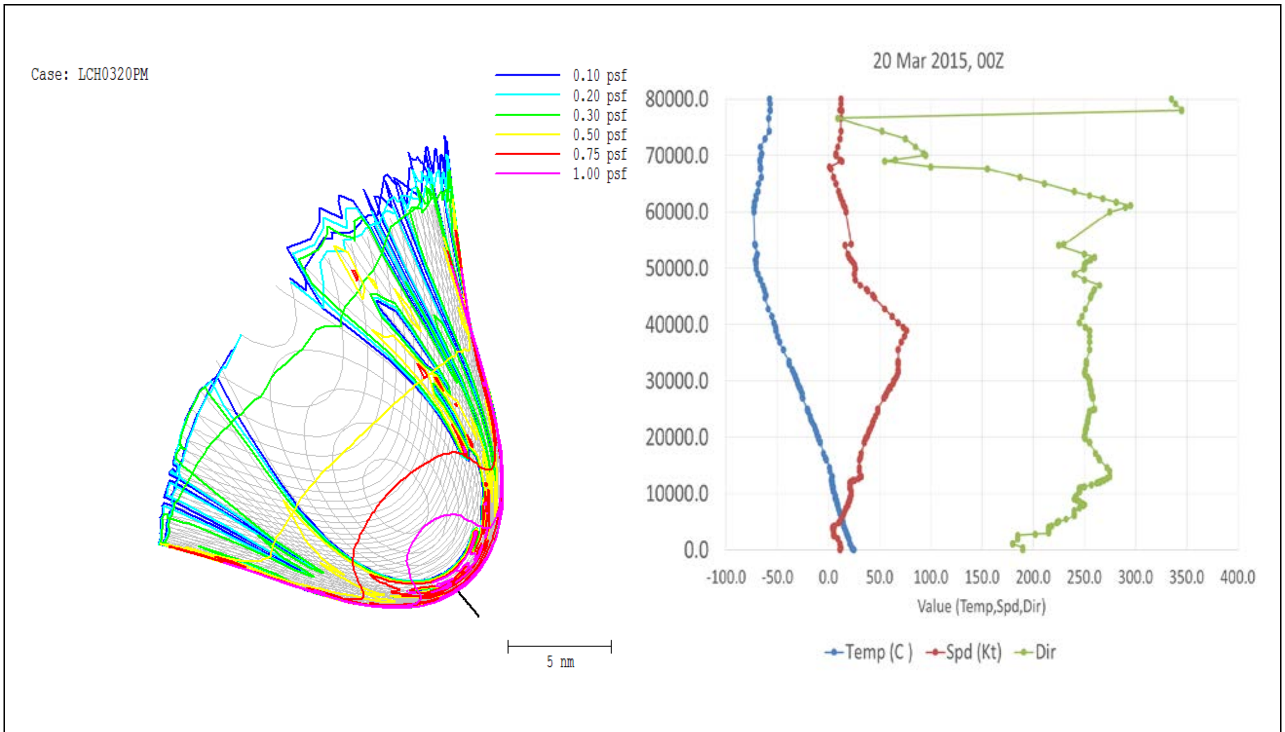

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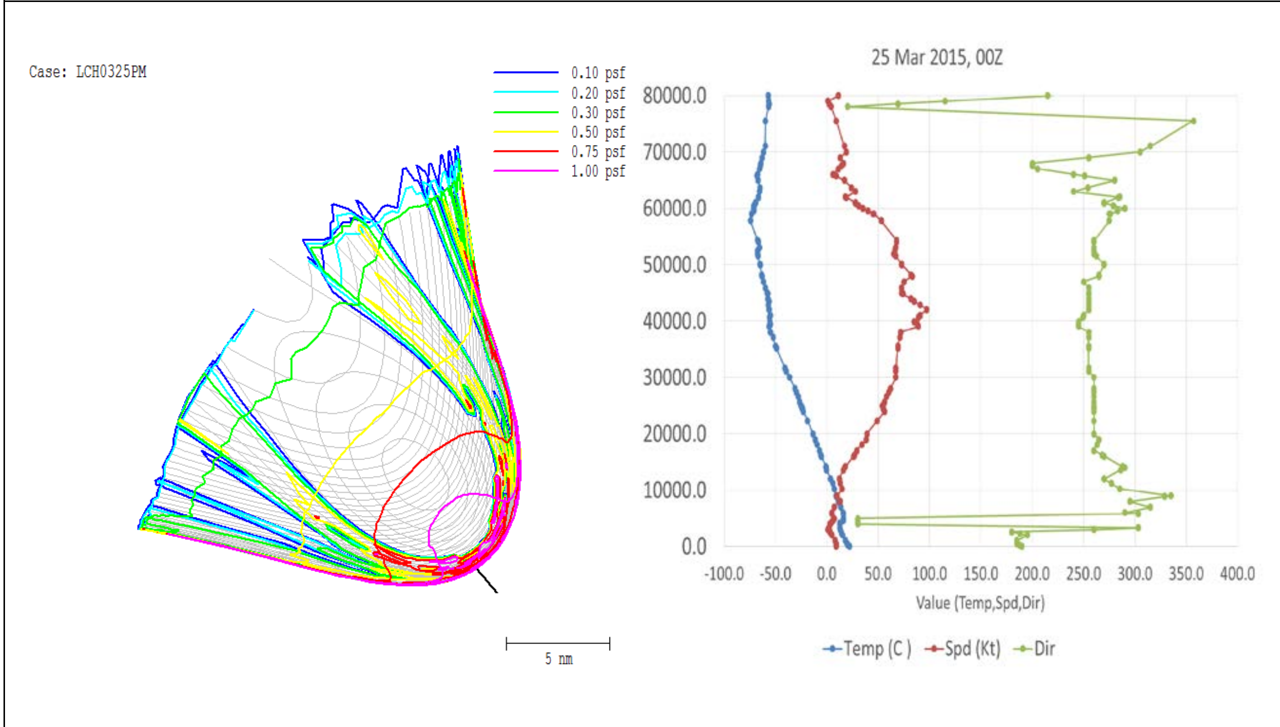

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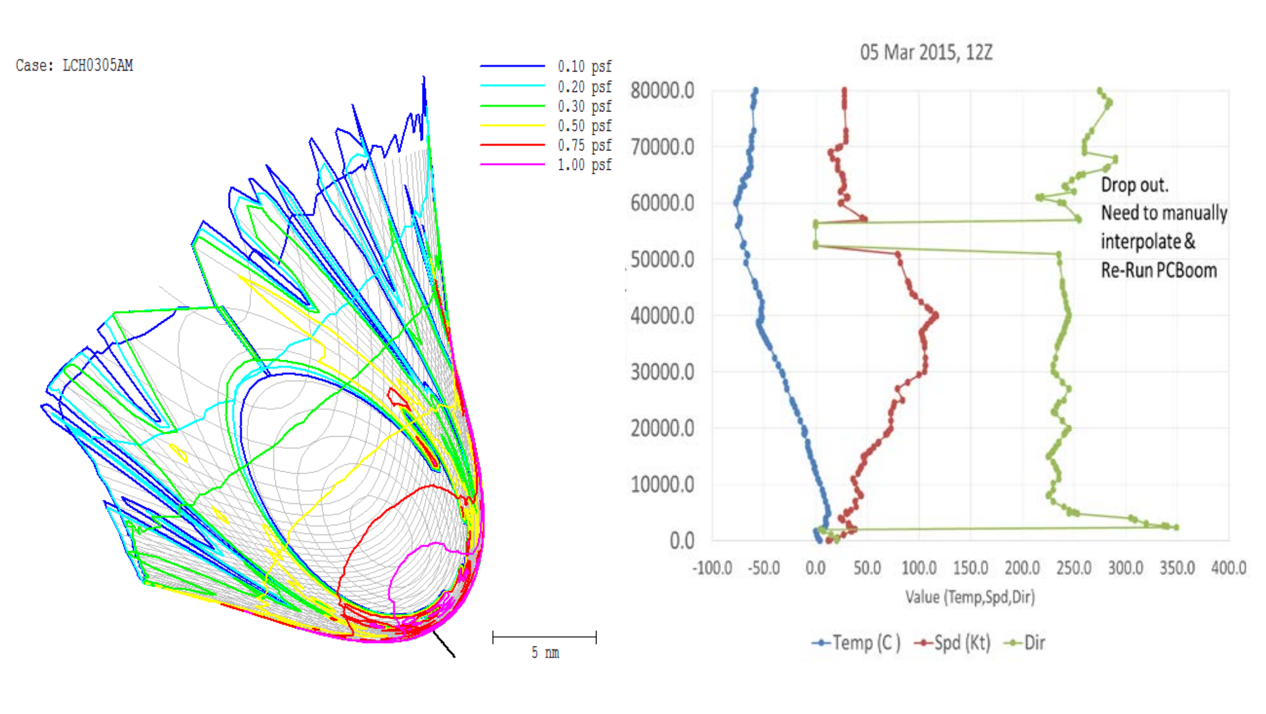

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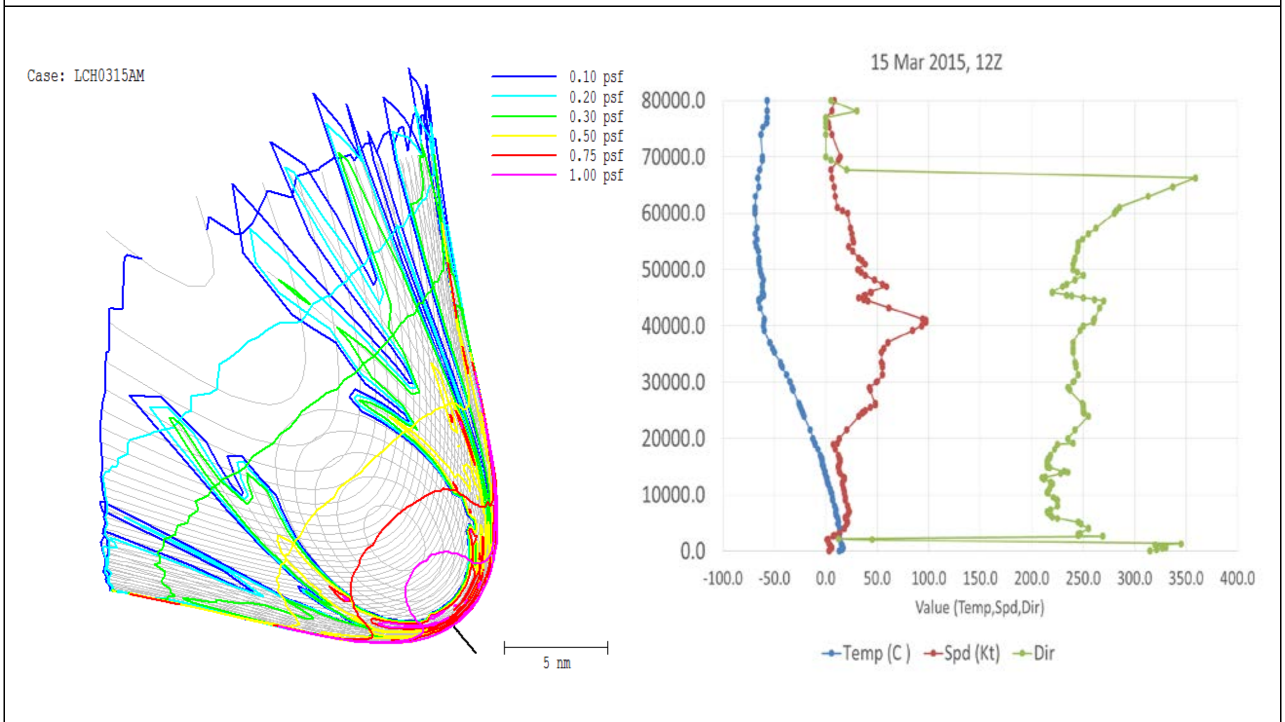

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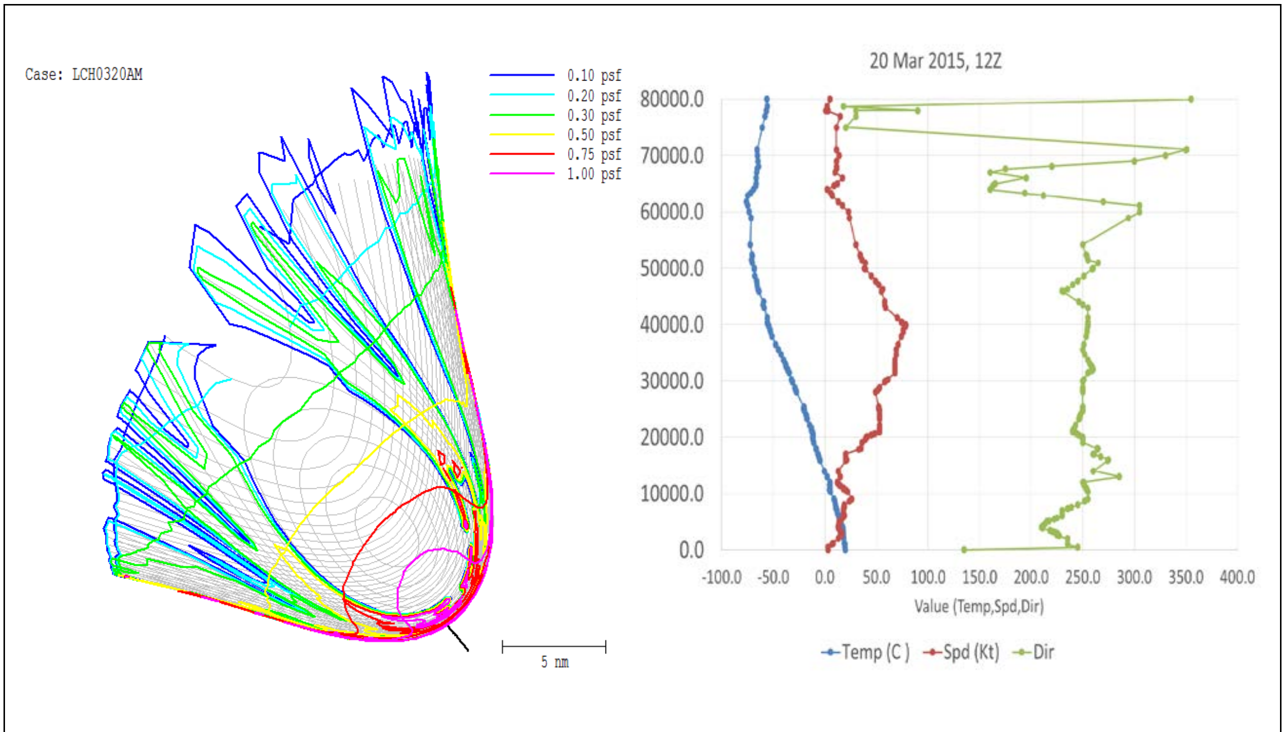

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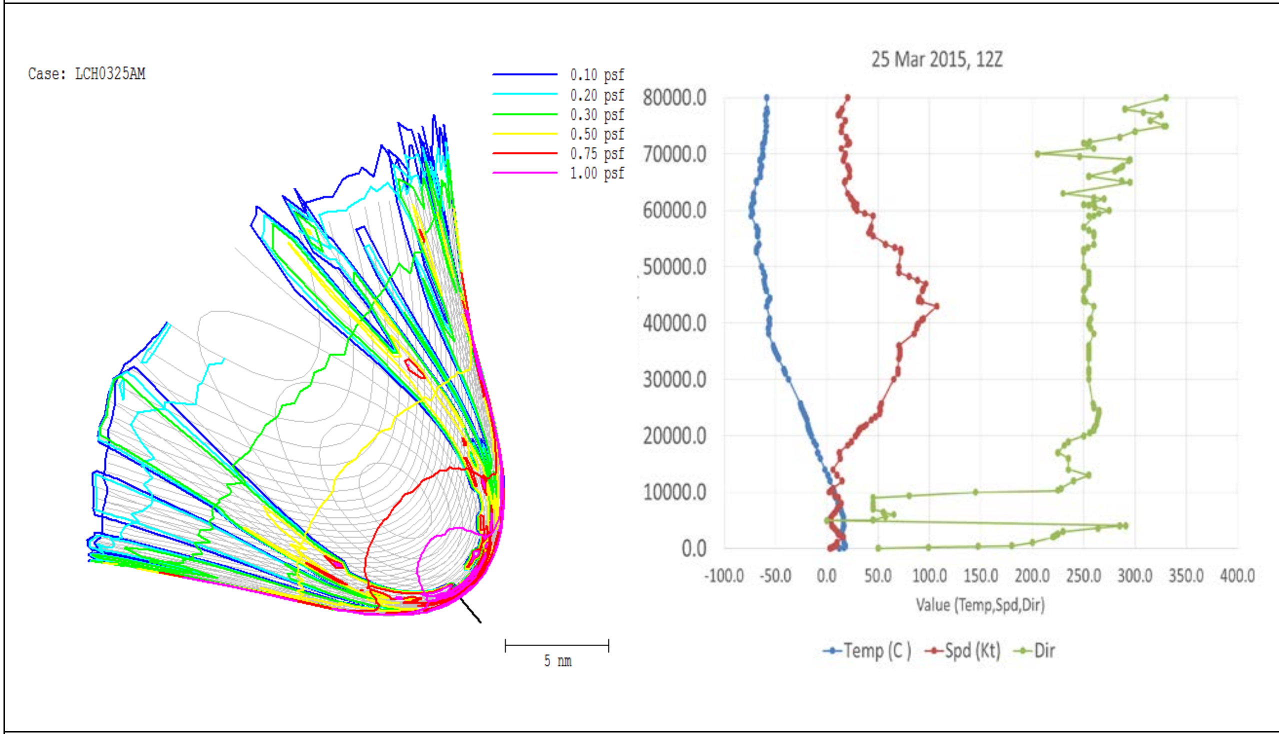


25 Mar 2015 1200 Zulu (5 AM Local) PCBoom Footprint and Meteorological Upper Air Sounding Data

C. Appendix – Sample Survey Templates

WSPRRR Baseline Survey Template modified from
WSPR Low Boom Response Pilot Program Baseline Survey
Survey will be tested and finalized in Phase 2
To be formatted for administration by web and Smart Phone

Geolocation based questions will be refined and evaluated in Risk Reduction test
Daily Dose rating, and booms per location per day will be assessed in Risk Reduction test

---

You expressed interest in a research study about noise from quieter sonic booms. You have been selected to participate in the study, which is being conducted for research purposes to learn about people's reactions to sonic booms. Please answer a few questions about your neighborhood and your attitudes about noise.

Your participation is voluntary and confidential. The results of the study will be summarized so that the answers you provide cannot be associated with you or anyone in your household. You must be 18 years of age or older to consent to participate in this research. Responding to the survey questions implies your consent to participate. This team is affiliated with researchers from Penn State University. If you have any questions about this study, you can contact the Penn State Survey Research Center.

Location of home and place of work within test community

A1 Please confirm your street address. We have your address as <address>. Is this correct?
1 Yes (skip to A4)
2 No

A2 Are you still living in "insert: community name in site area"?
1 Yes
2 No (ineligible)

A3 Please provide your current home address.

A4 How many years have you lived at this home address?

_____ [enter number of years]
_____ Less than 1 full year

A5 Are you working in "insert: community name in site area"?
1 Yes
2 No (ineligible)

A6 Please provide your current work address.

A7 How many years have you been working at this address?

_____ [enter number of years]
_____ Less than 1 full year

Experience with Neighborhood Noises

B1 We are interested in the noises that people hear in their neighborhood. Do you think your neighborhood is quiet or noisy or about average?

1 Quiet
2 Noisy
3 Average

B2 Can you provide more information about why you feel that way?

B3 For each statement below, please tell me if you strongly disagree, moderately disagree, neither agree nor disagree, moderately agree or strongly agree.

a. I believe that people have a hard time getting used to noise.
b. I believe that with time most people adapt to noise.
c. I believe that with time I can adapt to noise.
d. I believe that with time I can get used to even the loudest noise.

1 Strongly disagree
2 Moderately disagree
3 Neither agree nor disagree
4 Moderately agree
5 Strongly agree

B4 The following is a list of noises that might occur in your neighborhood. Please indicate how much each noise bothers, disturbs or annoys you. Use a scale from 0 to 10 where 0 means “not at all bothered or annoyed” and 10 means “extremely bothered or annoyed.”

When you are at home, how much does noise from < noise source > bother, disturb, or annoy you? Please use a scale from 0 to 10 where 0 means “not at all” and 10 means “extremely.”

0 – 10 [Enter a number between 0 and 10]

a. _____ Barking Dogs
b. _____ Thunder
c. _____ Street traffic such as cars, trucks or motorcycles
d. _____ Commercial Aircraft noise
e. _____ Military aircraft noise

Social, Demographic and Building Characteristics

C1 What is your occupation?

C2 Including yourself, how many people live in your household?
_____ Number

C3 [IF C3 > 1] Do any children under age 6 live in your household?
1 Yes
2 No

C4 [IF C3 > 1] Including yourself, how many adults age 18 or older live in your household?
_____ Number

C5 What is your gender?
_____ Female
______Male

C6 In what year were you born? [Enter 4-digit year]
_____ Year

C7 Do you believe your hearing is normal, somewhat diminished or severely diminished?
1 Normal [go to C9]
2 Somewhat diminished
3 Severely diminished

C8 Describe extent of hearing problem.
[Enter detailed comments.]

C9 What is the highest grade or year of schooling that you completed? (Select one)

1 Grades 1 to 11
2 12th Grade No Diploma
3 High School Graduate or Equivalent (GED)
4 Some college, technical school, or 2-year degree
5 Bachelor's Degree (BA, AB, BS)
6 Some graduate work (no degree)
7 Masters, Doctoral, or Professional degree

C10 Which of the following best describes the type of home in which you live?
[SELECT ONE]
1 Single-family detached (no common walls)
2 Duplex or single-family attached (at least one common wall)
3 Apartment building or dormitory
4 Other *[SPECIFY]*

-

C11 Which of the following best describes the building type for your place of work?
[SELECT ONE]

1 Office building or restaurant 1 story
2 Office building or restaurant 2 stories
3 Office building, 2 to 4 stories
4 Office building taller than 4 stories
5 Big box store or warehouse
6 Shopping plaza (mini-mall)
7 Shopping mall
8 Other *[SPECIFY]*

C12 The research team may need to put noise monitoring equipment in residents' yards. This equipment may also requires an electrical power source for the equipment. Would you be willing to have noise or weather monitoring equipment located outdoors on your property and be able and willing to supply the power? *[SELECT ONE]*

[IF needed: the equipment requires standard household 110 volt electrical power]

1 Yes
2 No

Thank you! We appreciate your help with this research study.

WSPRRR Potential Daily Summary Survey Questions based on
WSPR Low Boom Response Pilot Program Daily Summary Survey
[To be formatted for administration by web and SmartPhone]

Geolocation based questions will be refined and evaluated in Risk Reduction test

Daily Dose rating, and booms per location per day will be assessed in Risk Reduction test

Self-administered questionnaire completed after each event by respondents

D1 Date: [MM/DD/YY]

D2 Time:

D3 Please indicate which parts of the day you were at home for at least one hour. [check all that apply]

1 Morning (8:00AM to Noon)
2 Afternoon (Noon to 5:00PM)
3 Evening (5:00PM to 7:00PM)
4 Other (Enter time period at home)___________

D4 Please indicate which parts of the day you were at work for at least one hour. [check all that apply]

5 Morning (8:00AM to Noon)
6 Afternoon (Noon to 5:00PM)
7 Evening (5:00PM to 7:00PM)
8 Other (Enter time period at work)____________

D5 During the time you were at home today, how many sonic booms did you hear?

Zero	None	[go to A9]
1 – 15	Enter number 1 to 15	

D6 During the time you were at work today, how many sonic booms did you hear?

Zero	None	[go to A9]
1 – 15	Enter number 1 to 15	

D7 For the next question, please think about the sonic booms you heard today whether you were at *home or at work* when you heard them.
Whether you were at home or at work, which of the following categories best describes how much the sonic booms that you heard today bothered, disturbed, or annoyed you? [select one]

Not at all annoying
Slightly annoying
Moderately annoying
Very annoying
Extremely annoying

D8 For the next questions, please think about the sonic booms you heard today where you were at *home* when you heard them.

D8a. Which of the following categories best describes how much the sonic booms that you heard at home bothered, disturbed, or annoyed you? [select one]
- Not at all annoying
- Slightly annoying
- Moderately annoying
- Very annoying
- Extremely annoying

D8b. How **loud** were the sonic booms at home?

(Not at all) 0 1 2 3 4 5 (Extremely)

D8c. How much did the sonic booms **interfere** with your activity at home?

(Not at all) 0 1 2 3 4 5 (Extremely)

D8d. Vibration is a motion. The motion may be seen or felt. How much **vibration** from the sonic booms did you see or feel at home?

(Not at all) 0 1 2 3 4 5 (A great deal)

D8e. Rattle is a type of noise that can occur when objects move due to a vibration. How much **rattle** from the sonic booms did you experience at home?

(Not at all) 0 1 2 3 4 5 (A great deal)

D9 For the next questions, please think about the sonic booms you heard today where you were at *work* when you heard them.

D9a. Which of the following categories best describes how much the sonic booms that you heard at work bothered, disturbed, or annoyed you? [select one]
- Not at all annoying
- Slightly annoying
- Moderately annoying
- Very annoying
- Extremely annoying

D9b. How **loud** were the sonic booms at work?

(Not at all) 0 1 2 3 4 5 (Extremely)

D9c. How much did the sonic booms **interfere** with your activity at work?

(Not at all) 0 1 2 3 4 5 (Extremely)

D9d. Vibration is a motion. The motion may be seen or felt. How much **vibration** from the sonic booms did you see or feel at work?

(Not at all) 0 1 2 3 4 5 (A great deal)

D9e. Rattle is a type of noise that can occur when objects move due to a vibration. How much **rattle** from the sonic booms did you experience at work?

(Not at all) 0 1 2 3 4 5 (A great deal)

D10 During the time you were at home today, were your windows closed most of the time or were they open most of the time?

1 Open most of the time
2 Closed most of the time

D11 During the time you were at work today, were your windows closed most of the time or were they open most of the time?

3 Open most of the time
4 Closed most of the time

D12 Did you hear any noises today that might have been sonic booms but you are not sure?

1 Yes
2 No [go to D13]

D13 Please describe what that noise sounded like. [text box]

D14 Please enter any additional comments. [text box]

WSPRRR Potential Single Event Survey Questions based on
WSPR Low Boom Response Pilot Program Single Event Survey
To be formatted for administration by web and SmartPhone

Geolocation based questions will be refined and evaluated in Risk Reduction test
** Single event rating will be assessed in Risk Reduction test**

Self-administered questionnaire completed after each event by respondents

E1 Date of the sonic boom:[MM/DD/YY]

E2 Time of the sonic boom:

E3 When the sonic boom occurred, were you…? [Select applicable location]
At home
At work
Other

E4 When the sonic boom occurred, were you…? [Select applicable location]
Indoors
Outdoors

E5 How much did the sonic boom **bother, disturb,** or **annoy** you?

(Not at all) 0 1 2 3 4 5 (Extremely)

E6 How **loud** was the sonic boom?

(Not at all) 0 1 2 3 4 5 (Extremely)

E7 How much did the sonic boom **interfere** with your activity?

(Not at all) 0 1 2 3 4 5 (Extremely)

E8 How much did the sonic boom **startle you** or **make you jump**?

(Not at all) 0 1 2 3 4 5 (Extremely)

E9 Vibration is a motion. The motion may be seen or felt. How much **vibration** from the sonic boom did you see or feel?

(Not at all) 0 1 2 3 4 5 (A great deal)

E10 Rattle is a type of noise that can occur when objects move due to a vibration. How much **rattle** from the sonic boom did you experience?

(Not at all) 0 1 2 3 4 5 (A great deal)

E11 Please enter any additional comments.

D. Appendix – Outreach: Background, Subtle Approach Rationale

Historical Background on Information Program for SST tests

The first tests were conducted in St. Louis, MO in 1961 to 1962. Prior to the first sonic boom, a public information program was initiated with a dinner presentation to civic leader and members of the news media providing information about the test. The informational program provided periodic new releases, films, and frequent lectures to community organizations (Borsky, 1965). However, the purpose of the study was not revealed to the approximately 1000 respondents to the interviews. The survey was describe as a broad community survey. The findings showed that 90% of the respondents indicated that the sonic booms interfered in some way, and 35% found the booms annoying. While only 0.6% filed formal complaints, complaining about commercial supersonic travel became socially acceptable. Among the findings, the researchers recommended that the next test investigate the influence a public-information program oriented to a commercial supersonic aircraft has on reactions to the boom in the next study.

The next test location was Oklahoma City, OK, in 1964. In January 1964, three weeks before the tests began, a sonic boom demonstration was conducted to provide sonic boom education and experience for community leaders. A detailed public information program was used to alert and inform communities about the sonic boom before any local booms actually occur. The program explained the purpose of the study and the characteristics of sonic booms. Meetings were held with public officials and civic leaders. Air Force officers explain the importance to the national defense program of realistic training programs of SAC. The nature of supersonic flights and sonic boom effects was also given. The program included a movie, interviews on local radio programs, articles in local papers, and speakers at organizations. The daily schedule of anticipated booms was released to the press, radio and TV stations in advance of the actual events, to minimize startle. Extensive local and national publicity openly stressed that the sonic booms were part of a test of human tolerance of the booms. It was made public that the continued development of an SST was dependent on whether the local population could accept the booms. Soon after the start of the booms, some groups urged acceptance of the booms and worked to discourage complaints, while other groups organized to stop the booms and encourage complaints. It was known from prior research that when respondents feel that their answers may affect some administrative or governmental action, there is the possibility that their responses will be skewed to achieve the desired outcome (Borsky, 1965).

The respondents were told that the survey was being conducted by the National Opinion Research Center (NORC). They were not told that the government was sponsoring the research, as there was a concern that respondents might shift their responses to influence government action. The researchers included questions to measure the extent to which respondents actually were aware of the purposes of the sonic booms, had heard of the study, or were connected with the FAA or the aviation industry, and whether or not they felt people should complain about the booms if they were annoyed by them. About one-third of all residents had direct ties with the aviation industry, but comparison of the annoyance ratings from those individuals and other respondents provided evidence that the connections did not appear to bias the responses. Almost 70% of all residents said they were aware of the purposes of the sonic boom tests at the time of the first interview, although only 5% of respondents were aware of the NORC study before they were interviewed. The researchers found that such a small group of knowledgeable participants could not realistically bias the overall findings, and as such, the public release of the announcement did not greatly affect the study. One group of respondents was viewed as potentially biased. Approximately 29% of all residents felt it was improper for a person to complain even if he was annoyed. The researchers recognized that reports of interference, annoyance, and desires to complain can be lower for persons who feel complaining is improper than for those who feel people should complain if annoyed. They determined that respondents with this belief might not be comfortable reporting negative reactions and removed their answers from the major findings and analyzed their responses as a separate group.

Although there was a large public information program only 5% of the respondents were aware of the study prior to participation. For the WSPRRR test design, given the current 24 hour news cycle, the constant coverage of media in newspapers, TV, radio and the internet and the ubiquitous nature of social media, it would be reasonable to assume that a much higher percentage of respondents would be exposed to a large public information campaign. More notably, groups within the general public began to campaign, either for, or against the concept of supersonic transport. *The potential for an external influence on the respondents from members of the general community was observed in the Oklahoma City test and is at the foundation of our determination to use a subtle approach to engage the first test community.*

Rationale for Initial Subtle Community Approach

The WSPRRR plan initiates a more subtle Outreach approach prior to the test, with a media based outreach effort after each Regional field test has been completed. This approach advocates maintaining a low profile initially to avoid large media coverage and the introduction of bias.

The test objective is to gather data to support regulatory review, and the proposed design considers the potential impact of media coverage on our data gathering process and how our findings are viewed. Positive media coverage could bias respondents, and could also be misconstrued as an attempt by our team to bias research participants to respond more positively. Negative media coverage could bias our respondents, and could result in potential community based objections that could delay the flight test. As such, we are delaying full media coverage until after the test. The information provided initially will consist of research test based content.

LBFD Test Design Community Engagement and Outreach Summary

This presents an outline for the LBFD Test Design Community Engagement and Outreach Approach.

Pre-Field Test Community Engagement Approach

The WSPRRR team can provide research test based information to the community.

6. For each field test community assess community infrastructure
    a. Be knowledgeable about demographics; government infrastructure; norms
    b. Be aware of cultures and diversity within community
7. Require English speaking participants. (multi-lingual approach beyond current scope)
8. Identify and work with leaders in local government, community organizations
    a. Local city, borough and township officials
    b. Identify other relevant community organizations
    c. Determine if any permits are required (not likely)
    d. Notify emergency responders as precaution (off design boom may prompt concern)
9. Identify research test based message content, determine potential information release options

Pre-test Engagement Options

5. Assess local noise attitudes via social media monitoring. Is there already a noise issue?
6. Identify local options for News Media outlets: Printed, TV, Radio, Web-based, newsletters
    a. Most communities have established community announcement outlets (TV, radio etc.)
    b. Media releases will most likely be delayed until after the test and treated as Outreach to ensure that all participants have the same instructions. Avoid the potential for media coverage to bias or affect respondents prior to participation.
7. Simulator Days: Use simulator to introduce/train a portion of the participants on low booms
    a. Implementation only practical in select locations with higher participant density
    b. Prepare research based materials for simulator days
    c. Provide auditory exposure/training to identify sound character/range of booms
    d. Low boom is on order of distant thunder or two car door slams in succession
    e. Ensure that participants hear full range of booms in simulator
    f. Keep record of which participants heard the range of booms in the simulator
    g. Record of respondents participation in familiarization can be variable in data analysis
    h. If a non-recruit member of the public shows interest, we won't turn them away
8. Use Social media monitoring as a form of proactive Outreach (leveraged through FAA ASCENT)
    a. Observations are to gauge community perspective and are not considered response data
    b. Draft post-test news release to address concerns expressed on social media

Outreach Approach (finalized under Phase 2)

The WSPRRR team can conduct initial community based Outreach and implement Outreach in LBFD test communities. A full National Supersonics Outreach campaign is a sufficiently important element that it is recommended that additional funds be allocated to this as a separate project, or support of National Outreach could be obtained separately from NASA and other funding agencies.

Multi-Community Based Outreach Plan (Implemented in LBFD test communities)

5. Form Outreach team with diverse agency membership
    a. WSPRR: Kathy Hodgdon, Juliet Page, Bob Hunte, Matt Collmar, Kevin Bradley
    b. NASA/DOT representatives from Supersonics, Outreach and public affairs offices
    c. FAA: Rick Riley, Sandy Liu, Becky Cointin (FAA ASCENT Outreach and Supersonics)
6. Work with NASA sponsor to utilize NASA Outreach resources
    a. NASA representatives for Outreach efforts to be determined
    b. Interactional dynamics with NASA Outreach to be determined
    c. Optimize NASA Outreach resources to conduct each community based effort
    d. Augment NASA resources with FAA resources such as NoiseQuest Outreach website

7. A nationwide Supersonics Outreach plan is outside the scope of this effort
8. Create content focus for individual communities
    a. Identify community specific outreach opportunities
    b. Present specific content relevant for individual communities

Multi-Community Outreach Approach (To be finalized under Phase 2)

7. Form Outreach team with diverse agency membership
8. Target specific audiences (government entities, participants) after community field test
9. Develop an educational outreach plan to execute in multiple communities across each regional site
    a. Provide access to information and interactive learning experiences
    b. Foster public acceptance through education and understanding
10. Develop informational content designed to enhance knowledge, raise awareness
11. Develop STEM materials available as downloadable on NQ for classroom use
    a. Provide information on supersonic low boom related research
    b. Provide readily accessible information in PLAIN language approach
    c. Target 8th to 10th grade reading level
    d. Share advanced technology and underlying concepts
    e. Acknowledge challenges
    f. Inspire students and travelers to imagine the future
12. Design and implement multi-method delivery approach
    a. Use FAA NoiseQuest for web based outreach
    b. Develop Posters/Presentations
    c. Use simulator for auditory familiarization/hands on education

Content Development Approach

8. Content will be presented in a variety of formats in easy to read language
9. Written content would be associated with informative images
10. Content would be initially written using technical language to ensure accuracy, and then edited to simplify the reading level.
11. A reading level of 8th to 10th grade will be targeted to match the national reading level
12. Some content may not lend itself readily to a 10th grade reading level. Accuracy would be maintained, and the content would be simplified as much as possible.
13. Relevant video links would be identified to provide multi-media learning opportunities

Outreach Vision for content development

8. *Imagine* the future
9. *Inspire* future generations of students and travelers
10. *Share* advanced technology and underlying concepts
11. *Acknowledge* challenges
12. Multiple modes of presentation and interactions
13. STEM educational outreach options (Options finalized under Phase 2)
    a. Web-based education
    b. Public meetings
    c. Media based
    d. Written publications
    e. Flyers/Handouts/Pamphlets/Newsletters
    f. Compliant w/ Plain Language Public Law 111-274

References:
Nixon, Charles W. and Borsky, Paul N., Effects of Sonic Boom on People: St. Louis, Missouri, 1961- 1962 Journal of the Acoustical Society of America, Volume 39, Number 5, part 2, 1966.

Borsky, Paul, N., "Community reactions to sonic booms" National Opinion Research Center Report # 87, NASA CR 57022, August 1962.

Borsky, Paul, N., Community reactions to sonic booms In the Oklahoma City area Volume I: Major Findings" National Opinion Research Center Report #101 January 1965.

E. Appendix. Site Selection Details – Central United States

During the WSPRRR Phase 1 Final Review, questions were raised regarding the lack of bases of operations in the western section of the “Cold” climate region (as defined in Building America Best Practices). In response to these questions, additional review was done to confirm that no sites in this region met the criteria specified in the site selection process, and to analyze and explain the constraints and limitations of a few potential sites. As presented inFigure E-1, the sites that were re-examined were Mountain Home AFB (Boise, ID), Hill AFB (Salt Lake City, UT), and Buckley AFB (Denver, CO). These sites met the appropriate runway length conditions specified in the S.O.W., and also are non-commercial bases.

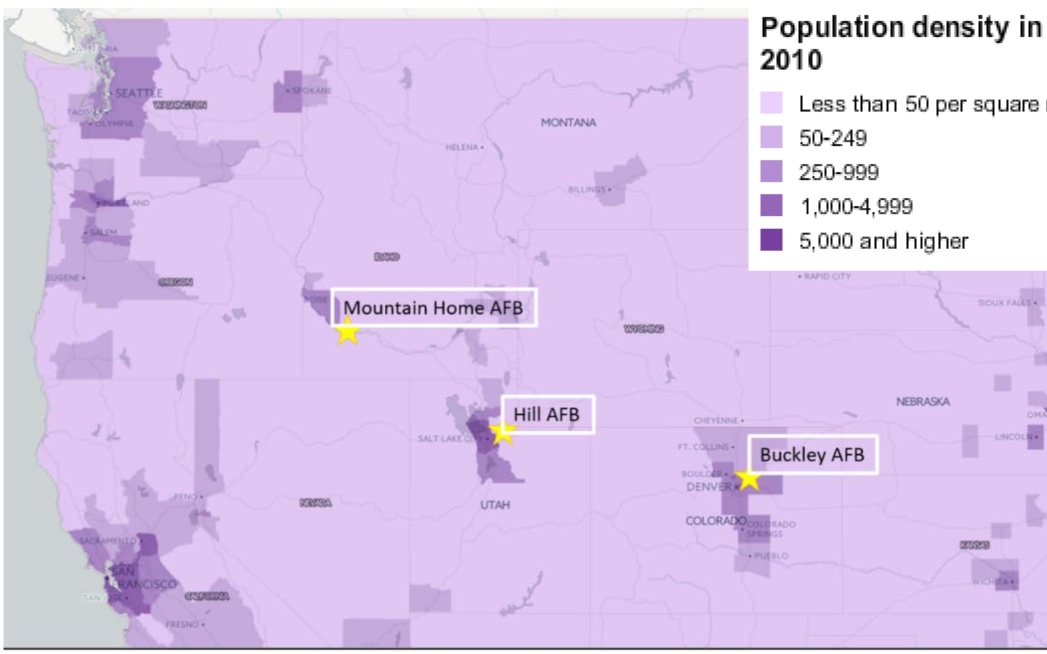


Figure E-1 Western Sites re-examined in response to questions raised in the Final Review

The most limiting factor in the process of selecting a base of operation and recruiting communities is locating an appropriate area for placement of the climb/acceleration focus boom footprint. The focus boom is significantly louder and more intrusive than the booms produced in the carpet region (Figure E-2 &Figure E-3) and could contribute to negative media attention, especially because the population affected will not be participating in recruitment. The extra affected population would require additional outreach for the purpose of educating to avoid unexpected negative public reaction. In all of the sites selected and presented in the final report, the focus boom is placed over a large body of water to avoid disturbing any populations around the study area. It is mainly for this reason that study areas in the middle of the country were not chosen.

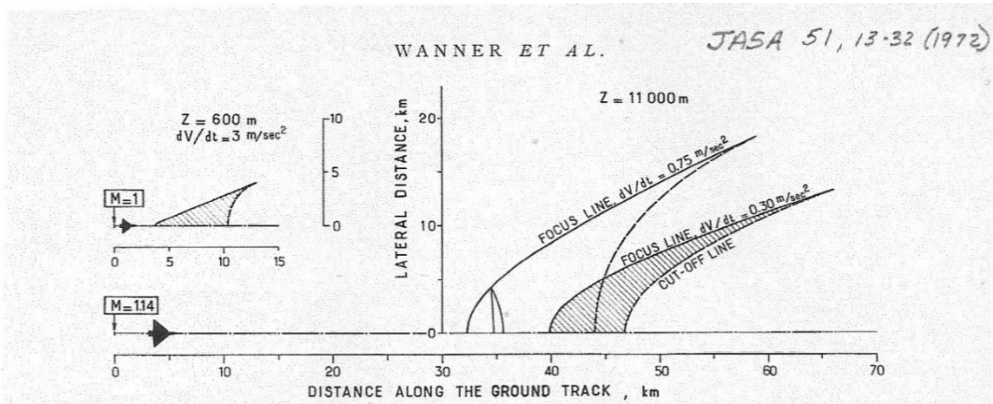


FIG. 2. Comparison at the same scale of the zones involved by focus during accelerated flights. (1) $Z=600$ m (2000 ft), $dv/dt=3$ m/sec² (10 ft/sec²); (2) $Z=11\,000$ m (36 000 ft), $dv/dt=0.15$ m/sec² (2.5 ft/sec²); (3) $Z=11\,000$ m (36 000 ft), $dv/dt=0.3$ m/sec² (1 ft/sec²).

Figure E-2 Focus Zones during accelerated flight

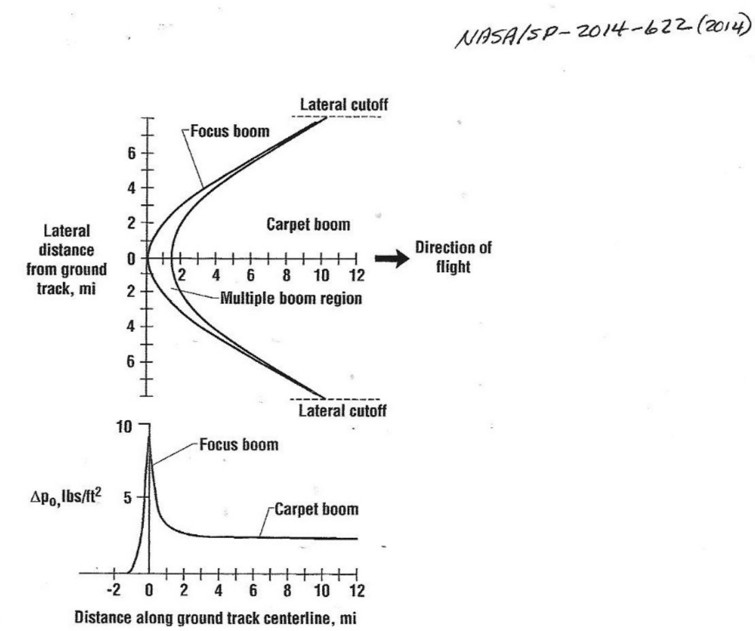


Figure E-3 Predicted focus boom region along ground track during SR-71 transition flight, distance along ground track, mi.

(Source: NASA SP 2014-622; Plotkin 1993)

One way to avoid disturbing a significant amount of people with the focus boom is to place the footprint over a sparsely populated area. This option was explored for the Midwest region, but additional constraints arose out of this approach. In this area of the U.S., high population density areas are usually more concentrated than population areas near the coasts, which limits flight path options due to aircraft range limits, and also results in less variation of housing and neighborhood types. In addition to being more concentrated, higher population density area tend to be less “expansive” geographically than their costal counterparts. This limits the number and availability of communities distributed across the carpet region. Flight paths would have to be altered in order to obtain dose response from directly undertrack and towards the lateral cutoff and it could result in fewer exposures per flight.

Another potential issue specifically with the sites reviewed is elevation above sea level, which can potentially affect aircraft flight performance and boom noise levels. Both Hill AFB and Buckley AFB (and their surrounding communities) are between 4,500 ft. MSL and 5,500 ft. MSL. In order to hold testing consistent across the six regional test sites, this elevation might require the LBFD at a higher altitude in order to keep the propagation distance between the aircraft and the communities constant. In addition, meteorological conditions such as wind speed and temperature may be different at higher altitudes. More analysis using the final LBFD design will be necessary to fully understand the robustness of the low boom design for reduced propagation distances and any associated flight performance impacts.

It is for a combination of the factors presented that no bases of operation were chosen in the Midwest region of the country. We expect to have a representative total sample with the six sites presented in the WSPRRR Final Report. Figure E-4 through Figure E-9 are included to further illustrate our assessment of available population at each of these sites.

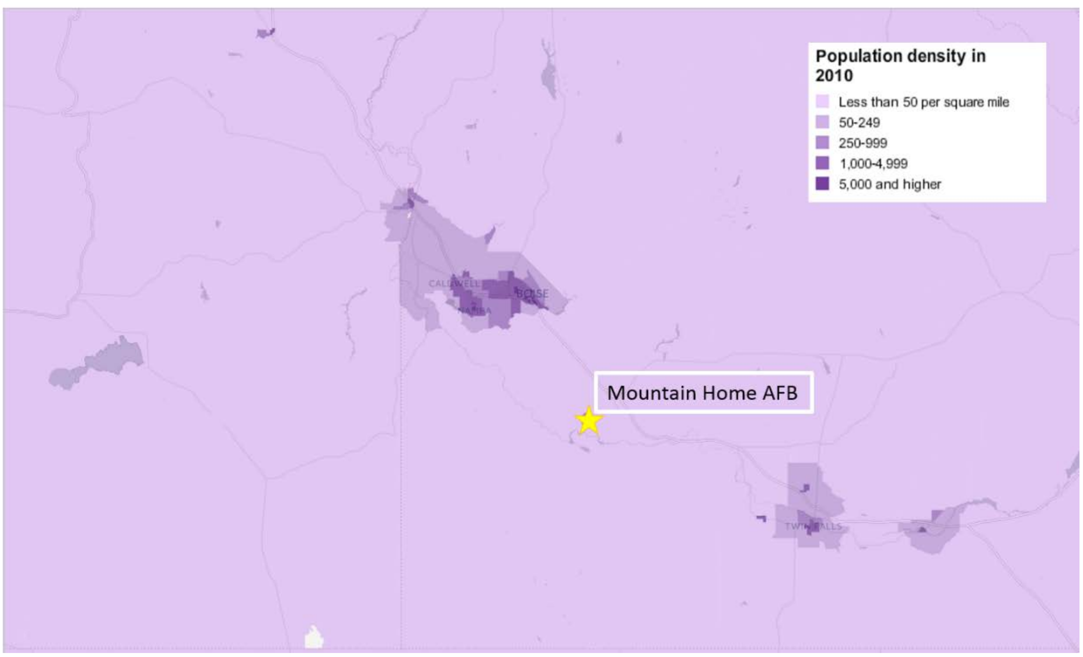


Figure E-4 Mountain Home AFB – Population Density

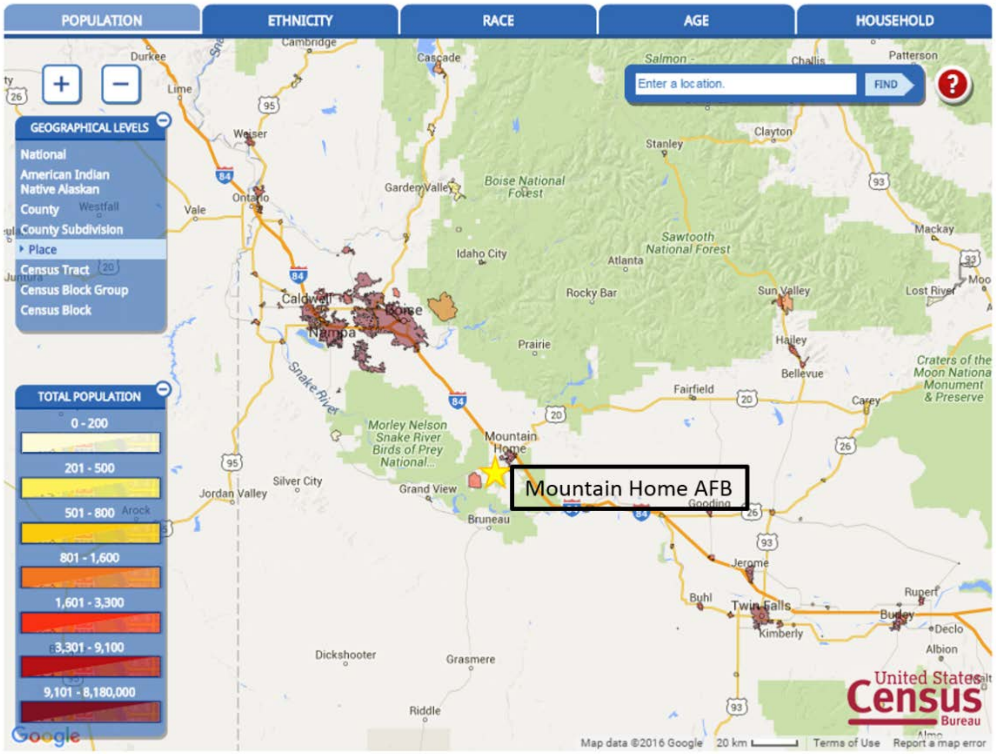


Figure E-5 Mountain Home Population Places

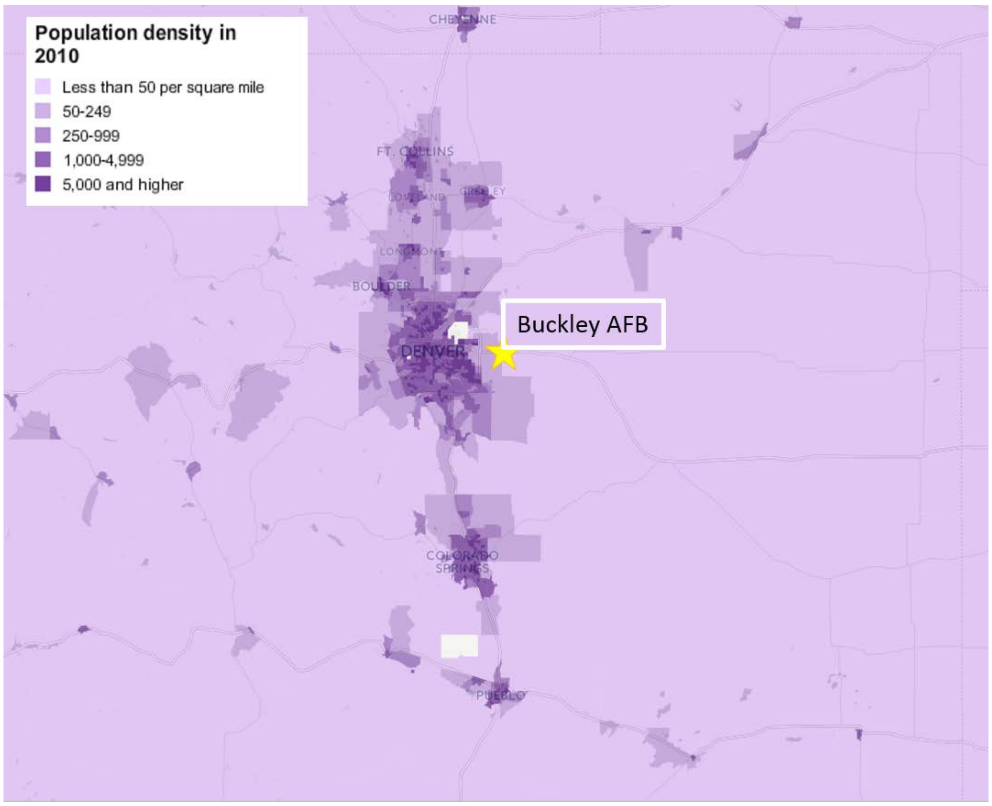


Figure E-6 Buckley AFB Population Density

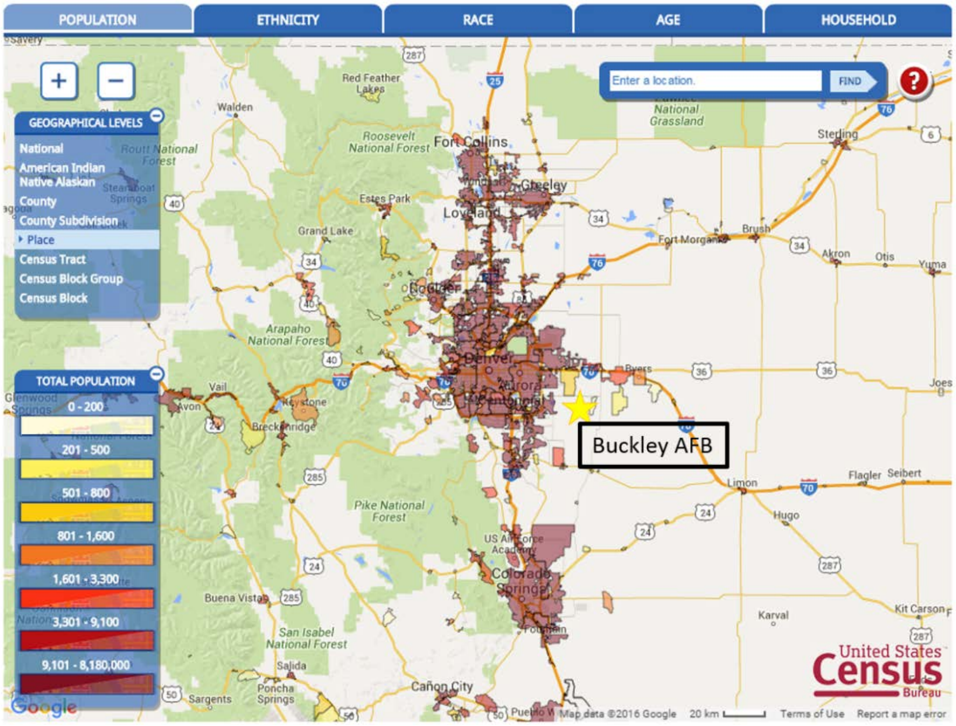


Figure E-7 Buckley AFB Population Places

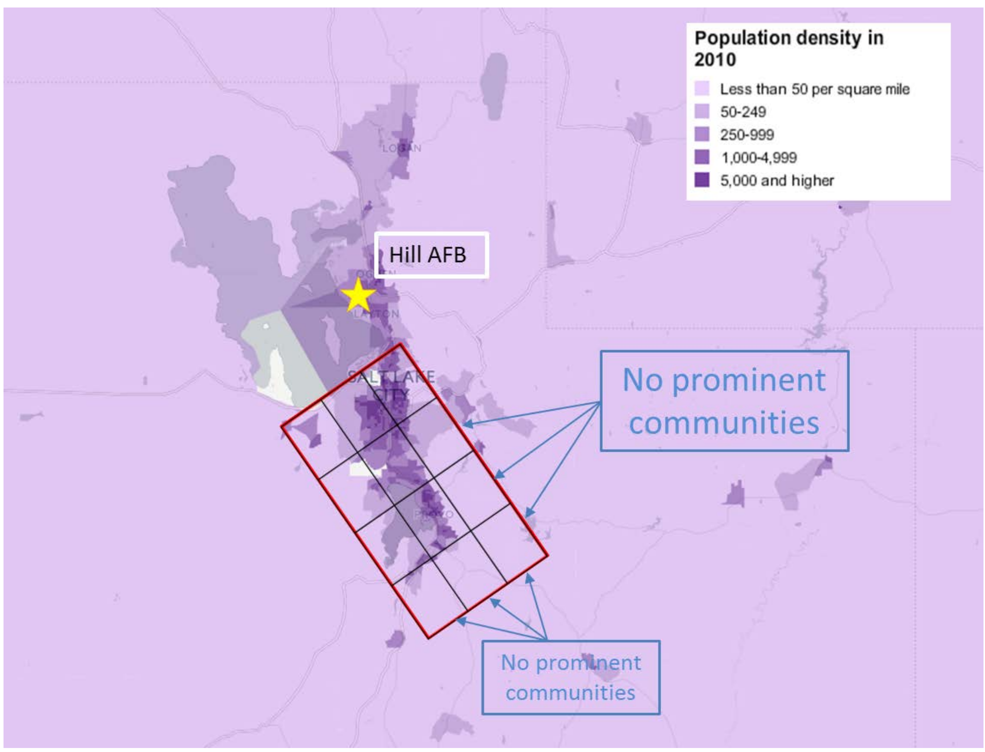


Figure E-8 Hill AFB Population Density

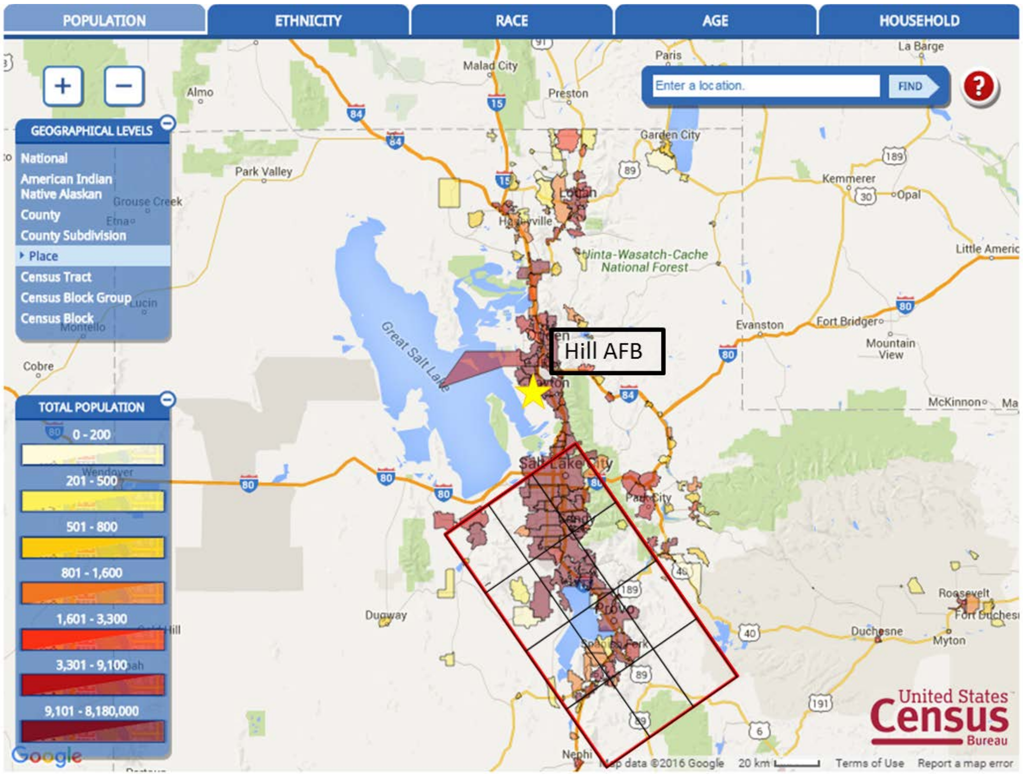


Figure E-9 Hill AFB Population Places

Appendix E References

Plotkin, Kenneth J., 1993. “Sonic Boom Focal Zones from Tactical Aircraft Maneuvers”, Journal of Aircraft, Vol. 30, No.1, Jan-Feb.

Maglieri, D.M., Percy J. Bobbitt, Kenneth J. Plotkin, Kevin P. Shepherd, Peter G. Coen, David M. Richwine, 2014. Sonic Boom: Six Decades of Research, NASA SP-2014-622.

F. Risk Assessment

There are 33 risks in the inventory for which high level mitigation strategies have been identified. Each risk has been assigned a probability of occurrence (remaining after the proposed mitigation) as well as the consequence for each design element. The resulting impact to a given design element was calculated as the product of the probability of occurrence and the consequence. The top row of Table F-1 reflects the distribution of total impact across design elements with the majority residing in #8 Data Analysis, #4 Survey and Dose Response, #5 Survey Implementation and Recruitment, and #7 Boom Analysis. The risks are sorted by their total impact to the experiment across all design elements, this is calculated as the sum of the impact to each design element and is reflected in the right most column.

Table F-1 Risk Assessment

For those risks with total impact across all design elements greater than the mean

	Risk Title	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	
	Mean									24.15
	Total	63	54	80	137	121	88	108	146	
27	Participant location determination	0	0	0	16	12	8	16	16	68
25	Participant response motivation	0	0	12	12	12	0	0	12	48
26	Participant recruitment challenges	12	3	0	9	12	0	0	9	45
33	Determination of Noise at a Participant's location	0	0	0	8	0	12	12	12	44
8	Noise Monitoring across large carpet region	0	9	0	0	9	9	9	0	36
21	Cross Community Comparison	4	4	4	8	4	4	4	4	36
23	No Subjective response (Participants didn't hear it)	0	0	0	12	4	0	0	16	32
1	Transition Focused Footprint	4	5	5	2	3	3	5	3	30
2	Climb booms	4	5	5	2	3	3	5	3	30
30	Flight Trajectory Precision	6	6	2	2	2	2	6	4	30
22	low boom signature is a new noise source	0	0	4	8	12	0	0	4	28
17	Media Response	9	0	9	0	0	0	0	9	27
18	Startle or rattle	0	6	0	9	0	0	0	9	24
20	Sleep Disturbance Complexity	0	0	6	9	0	0	0	9	24
28	Low frequency building excitation	6	0	0	0	0	9	0	9	24
32	Geolocation through Qualtrics	0	0	0	0	12	0	0	12	24
24	FAA Activity Conflicts	4	2	3	4	3	0	3	3	22
13	Structural Damage not due to LB	0	0	0	4	8	0	8	0	20
14	Boom level enhancement through structural configuration	0	0	0	4	8	0	8	0	20
4	Turbulence Allowances for Noise Dose	2	0	0	4	0	6	6	0	18
5	Diurnal Affect	2	4	0	4	0	4	4	0	18
29	IRB/OMB Approval	0	0	9	0	9	0	0	0	18
31	Introduction of bias vs an informed community	0	0	9	0	0	0	0	9	18
7	Atmospheric variability	2	6	0	4	0	0	4	0	16
12	Construction Variability	0	0	0	0	8	0	8	0	16
3	Supersonic Turn focus booms	4	4	0	4	0	0	0	0	12
9	Unattended/Remote controlled noise monitors	0	0	0	0	0	12	0	0	12
11	Interior Noise	0	0	0	0	0	6	6	0	12
16	Anecdotal Influence	0	0	6	6	0	0	0	0	12
6	Turbulence detection	2	0	0	0	0	4	4	0	10
19	Night Flights - Sleep Disturbance	0	0	3	3	0	0	0	3	9
10	Noise Monitor Security	2	0	0	0	0	6	0	0	8
15	Second effect damage/injury	0	0	3	3	0	0	0	0	6

The average of the total impact for the risks across all design elements is 24.15; twelve of the 33 risks are above this average with two having the highest impact rating (16) to one or more design elements: Risk #27 Participant Location Determination and Risk #23 No Subjective Response. Figure F-1 presents these twelve risks on a traditional Risk Cube.

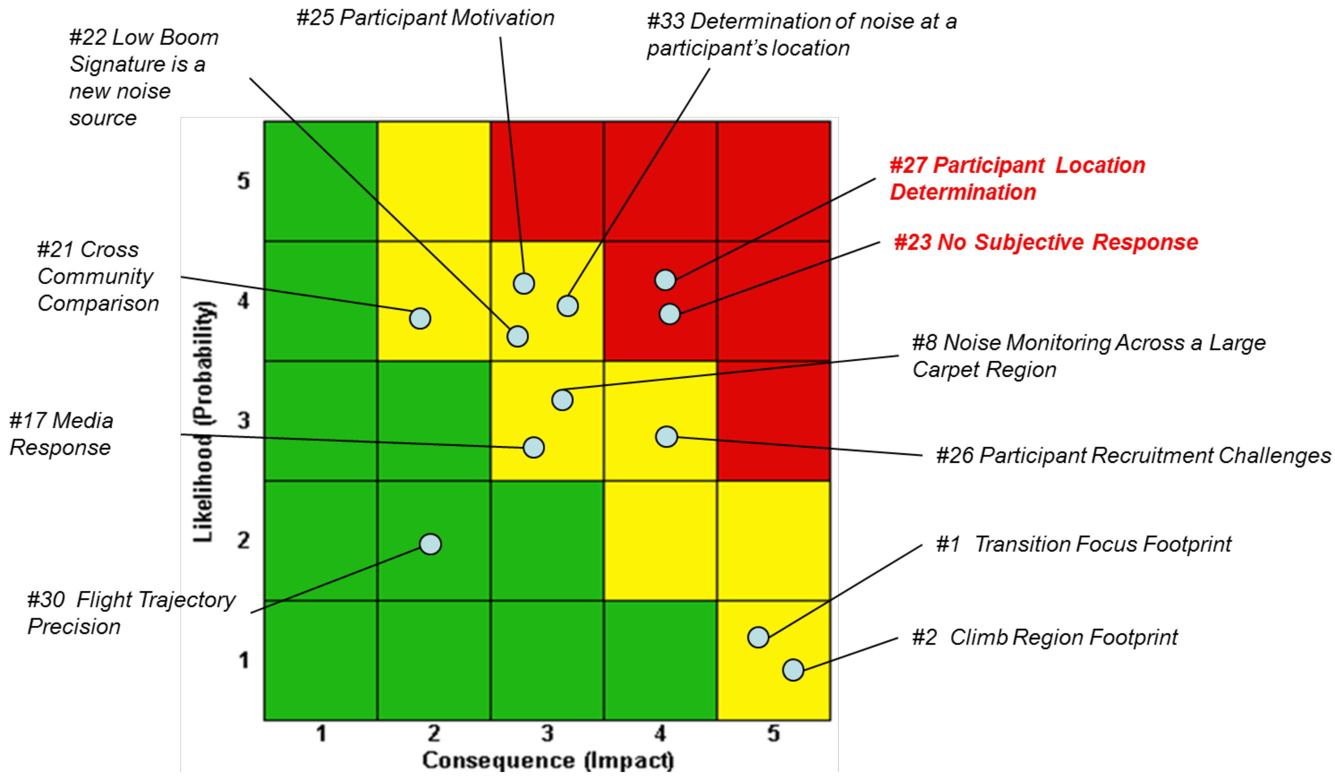


Figure F-1 Risk Cube Assessment of Significance

For those risks with total impact across all design elements greater than the mean.

Mitigation strategies have been defined at a high level for each risk; in some cases these strategies require further exploration in Phase 2. The following sections in this appendix denote each risk and its assessment from our Risk Inventory prioritized by overall impact as shown in Table F-1 Risk Assessment. While the parent document addresses the overall conceptual plan and phase 2 activities, we have associated relevant discussion from it with each individual risk; in some cases additional discussion from our risk inventory has been added as well.

#27 Participant Location Determination

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
27	Participant location determination	4				4	3	2	4	4	3	0	0	0	16	12	8	16	16	68

- Condition:
  - NASA's objective is to understand the community response to sonic boom noise generated by low-boom supersonic aircraft. This requires correlation of the participant's response with the acoustic measurement of the low boom to which they responded.
- Departure:

  - Noise monitors will be deployed at fixed locations throughout the communities. Participants will be required to live and work within the carpet boom area but will not be constrained in their movements during this experiment.
- Affected Asset:
  - Correlation of sonic boom measurements with the subjective response (Where the participant is amongst the noise monitors)
- Consequence:
  - In order to determine the participant Noise Dose for correlation with their response, we must be able to determine where participants were when they experienced the low boom so as to determine their geographic location with respect to the sonic boom monitors. We anticipate some variation in the low boom across the community, we must know which monitors the participant was nearest to in order to infer the noise dose that they experienced.
- Mitigation:

The survey design will include questions concerning the participant's location when they experienced the low boom. Additionally we plan to use a feature of Qualtrics™ which provides the latitude and longitude position of a participant responding through the Qualtrics survey app on a GPS-enabled device. The Penn State University Survey Research Center (SRC) has developed a simple prototype survey to determine the extent to which we can determine a participant's location when they respond to a single event survey (See Figure F-2) utilizing the Qualtrics application. In compliance with IRB requirements, the respondent will need to consent to have this feature enabled. The informed consent and instructions will ensure that locations services are enabled on their mobile device and that they allow their location to be retrieved and sent through the mobile survey application.

This prototype utilizes a web app developed by Qualtrics™ which provides the latitude and longitude position of a participant responding through the Qualtrics survey app on a GPS-enabled device. In compliance with IRB requirements, the respondent will need to consent to have this feature enabled. The informed consent and instructions will ensure that locations services are enabled on their mobile device and that they allow their location to be retrieved and sent through the mobile survey application.

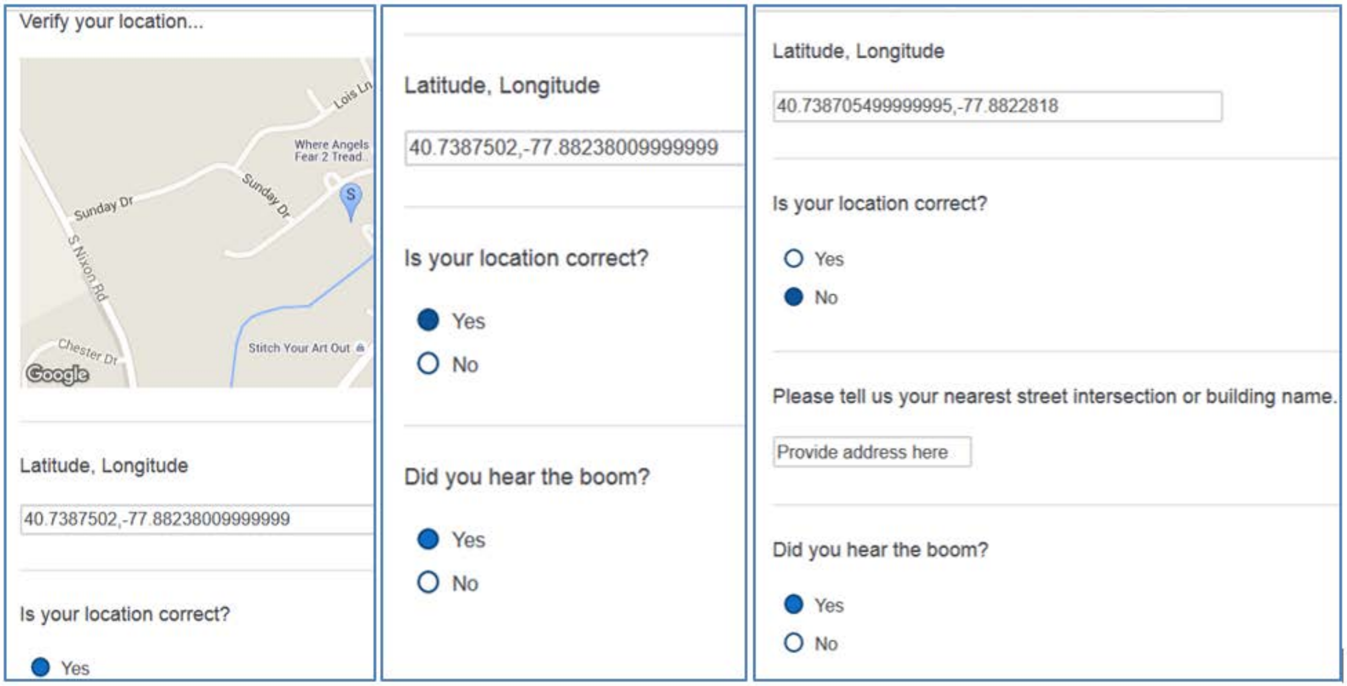


Figure F-2 Geo-location survey implementation

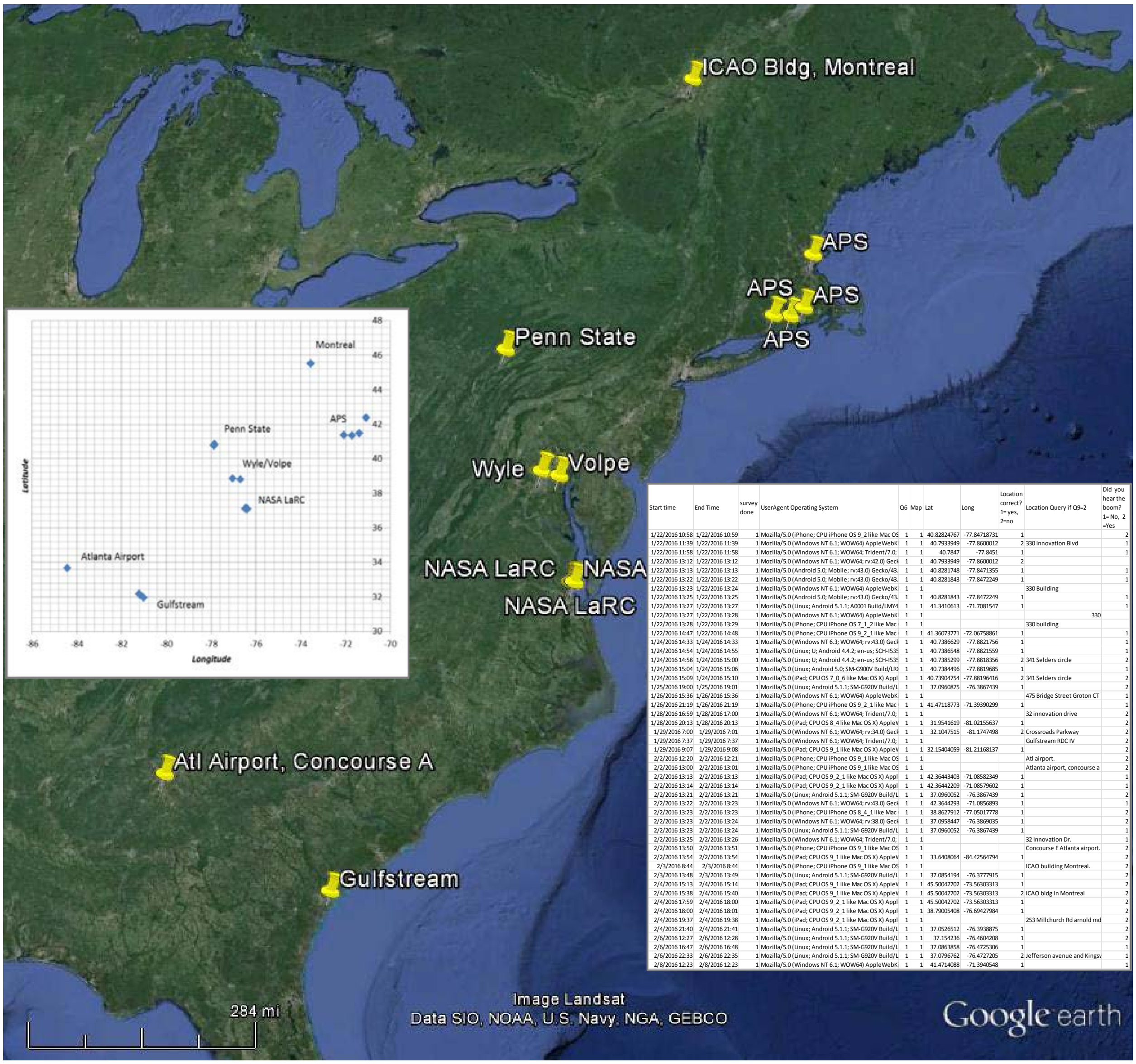
The data provided includes columns that show the longitude and latitude of the respondent. If they are unwilling to use this we can still get valuable data from their survey responses, by asking them to provide the address from which they are responding. For participants taking the survey using the Qualtrics Surveys app on a GPS-enabled device, Location Accuracy represents a radius in meters from the reported longitude and latitude in which the participant may be located. A larger number indicates a less accurate location.

If the respondent does not have a GPS-enabled device, the survey app will identify a location that is an approximation determined by comparing the participant's IP address to a location database. Inside the United States, this data is typically accurate to the city level. Where location is approximated, the longitude and latitude presented are of the geographic center of the most accurate location available for the respondent.

Our team successfully tested iPhones, androids, iPads, and laptops. As shown in Figure 3 the survey provides a map of the respondent's location. The survey asks if the location is correct. If the respondent replies "Yes", the latitude and longitude are used as the location. If the respondent replies "No" the application presents a query that states: "Please tell us your nearest street intersection or building name", followed by a box for the respondent to type their address.
With some of the networked laptops at Penn State, the location provided was the geographic center of the area. This served as an example of a system that did not have the GPS enabled. If the respondent does not have a GPS-enabled device, the app compares the IP address to a location database to get approximate location accurate to the city level. In this case, the longitude and latitude for approximate locations are presented as the geographic center of the most accurate location available. The Qualtrics application generates tabular data for each respondent, showing variables such as the time, the user operating system, the latitude and longitude, survey response, etc. The map in Figure F-3 shows the

response locations, with insets that present a sample spreadsheet of tabular responses from tests across the country and an inset of the locations of the tests of the GPS enabled Qualtrics survey application.

We recommend further testing to quantify the accuracy of the geo-location function during Phase 2. As stated in Section 4.3 of our Conceptual Test Plan, this needs to include device, carrier, and other appropriate variables. We will leverage ASCENT support in conducting this additional testing in Phase 2.



Start time	End Time	survey done	UserAgent Operating System	Q6	Map	Lat	Long	Location correct? 1= yes, 2=no	Location Query if Q9=2	Did you hear the boom? 1= No, 2 =Yes
1/22/2016 10:58	1/22/2016 10:59	1	Mozilla/5.0 (iPhone; CPU iPhone OS 9_2 like Mac OS	1	1	40.82824767	-77.84718731	1		2
1/22/2016 11:39	1/22/2016 11:39	1	Mozilla/5.0 (Windows NT 6.1; WOW64) AppleWebKi	1	1	40.7933949	-77.8600012	2	330 Innovation Blvd	1
1/22/2016 11:58	1/22/2016 11:58	1	Mozilla/5.0 (Windows NT 6.1; WOW64; Trident/7.0;	1	1	40.7847	-77.8451	1		1
1/22/2016 13:12	1/22/2016 13:12	1	Mozilla/5.0 (Windows NT 6.1; WOW64; rv:42.0) Geck	1	1	40.7933949	-77.8600012	2		
1/22/2016 13:13	1/22/2016 13:13	1	Mozilla/5.0 (Android 5.0; Mobile; rv:43.0) Gecko/43.	1	1	40.8281748	-77.8471355	1		1
1/22/2016 13:22	1/22/2016 13:22	1	Mozilla/5.0 (Android 5.0; Mobile; rv:43.0) Gecko/43.	1	1	40.8281843	-77.8472249	1		1
1/22/2016 13:23	1/22/2016 13:24	1	Mozilla/5.0 (Windows NT 6.1; WOW64) AppleWebKi	1	1				330 Building	
1/22/2016 13:25	1/22/2016 13:25	1	Mozilla/5.0 (Android 5.0; Mobile; rv:43.0) Gecko/43.	1	1	40.8281843	-77.8472249	1		1
1/22/2016 13:27	1/22/2016 13:27	1	Mozilla/5.0 (Linux; Android 5.1.1; A0001 Build/LMY4	1	1	41.3410613	-71.7081547	1		1
1/22/2016 13:27	1/22/2016 13:28	1	Mozilla/5.0 (Windows NT 6.1; WOW64) AppleWebKi	1	1				330	
1/22/2016 13:28	1/22/2016 13:29	1	Mozilla/5.0 (iPhone; CPU iPhone OS 7_1_2 like Mac	1	1				330 building	
1/22/2016 14:47	1/22/2016 14:48	1	Mozilla/5.0 (iPhone; CPU iPhone OS 9_2_1 like Mac	1	1	41.36073771	-72.06758861	1		1
1/24/2016 14:33	1/24/2016 14:33	1	Mozilla/5.0 (Windows NT 6.3; WOW64; rv:43.0) Geck	1	1	40.7386629	-77.8821756	1		1
1/24/2016 14:54	1/24/2016 14:55	1	Mozilla/5.0 (Linux; U; Android 4.4.2; en-us; SCH-I535	1	1	40.7386548	-77.8821559	1		1
1/24/2016 14:58	1/24/2016 15:00	1	Mozilla/5.0 (Linux; U; Android 4.4.2; en-us; SCH-I535	1	1	40.7385299	-77.8818356	2	341 Selders circle	2
1/24/2016 15:04	1/24/2016 15:06	1	Mozilla/5.0 (Linux; Android 5.0; SM-G900V Build/LRX	1	1	40.7384496	-77.8819685	1		1
1/24/2016 15:09	1/24/2016 15:10	1	Mozilla/5.0 (iPad; CPU OS 7_0_6 like Mac OS X) Appl	1	1	40.73904754	-77.88196416	2	341 Selders circle	2
1/25/2016 19:00	1/25/2016 19:01	1	Mozilla/5.0 (Linux; Android 5.1.1; SM-G920V Build/L	1	1	37.0960875	-76.3867439	1		2
1/26/2016 15:36	1/26/2016 15:36	1	Mozilla/5.0 (Windows NT 6.1; WOW64) AppleWebKi	1	1				475 Bridge Street Groton CT	1
1/26/2016 21:19	1/26/2016 21:19	1	Mozilla/5.0 (iPhone; CPU iPhone OS 9_2_1 like Mac	1	1	41.47118773	-71.39390299	1		1
1/28/2016 16:59	1/28/2016 17:00	1	Mozilla/5.0 (Windows NT 6.1; WOW64; Trident/7.0;	1	1				32 innovation drive	2
1/28/2016 20:13	1/28/2016 20:13	1	Mozilla/5.0 (iPad; CPU OS 8_4 like Mac OS X) AppleV	1	1	31.9541619	-81.02155637	1		2
1/29/2016 7:00	1/29/2016 7:01	1	Mozilla/5.0 (Windows NT 6.1; WOW64; rv:34.0) Geck	1	1	32.1047515	-81.1747498	2	Crossroads Parkway	2
1/29/2016 7:37	1/29/2016 7:37	1	Mozilla/5.0 (Windows NT 6.1; WOW64; Trident/7.0;	1	1				Gulfstream RDC IV	2
1/29/2016 9:07	1/29/2016 9:08	1	Mozilla/5.0 (iPad; CPU OS 9_1 like Mac OS X) AppleV	1	1	32.15404059	-81.21168137	1		2
2/2/2016 12:20	2/2/2016 12:21	1	Mozilla/5.0 (iPhone; CPU iPhone OS 9_1 like Mac OS	1	1				Atl airport.	2
2/2/2016 13:00	2/2/2016 13:01	1	Mozilla/5.0 (iPhone; CPU iPhone OS 9_1 like Mac OS	1	1				Atlanta airport, concourse a	2
2/2/2016 13:13	2/2/2016 13:13	1	Mozilla/5.0 (iPad; CPU OS 9_2_1 like Mac OS X) Appl	1	1	42.36443403	-71.08582349	1		1
2/2/2016 13:14	2/2/2016 13:14	1	Mozilla/5.0 (iPad; CPU OS 9_2_1 like Mac OS X) Appl	1	1	42.36442209	-71.08579602	1		1
2/2/2016 13:21	2/2/2016 13:21	1	Mozilla/5.0 (Linux; Android 5.1.1; SM-G920V Build/L	1	1	37.0960052	-76.3867439	1		2
2/2/2016 13:22	2/2/2016 13:23	1	Mozilla/5.0 (Windows NT 6.1; WOW64; rv:43.0) Geck	1	1	42.3644293	-71.0856893	1		1
2/2/2016 13:23	2/2/2016 13:23	1	Mozilla/5.0 (iPhone; CPU iPhone OS 8_4_1 like Mac	1	1	38.8627912	-77.05017778	1		2
2/2/2016 13:23	2/2/2016 13:24	1	Mozilla/5.0 (Windows NT 6.1; WOW64; rv:38.0) Geck	1	1	37.0958447	-76.3869035	1		2
2/2/2016 13:23	2/2/2016 13:24	1	Mozilla/5.0 (Linux; Android 5.1.1; SM-G920V Build/L	1	1	37.0960052	-76.3867439	1		1
2/2/2016 13:25	2/2/2016 13:26	1	Mozilla/5.0 (Windows NT 6.1; WOW64; Trident/7.0;	1	1				32 Innovation Dr.	1
2/2/2016 13:50	2/2/2016 13:51	1	Mozilla/5.0 (iPhone; CPU iPhone OS 9_1 like Mac OS	1	1				Concourse E Atlanta airport.	2
2/2/2016 13:54	2/2/2016 13:54	1	Mozilla/5.0 (iPad; CPU OS 9_1 like Mac OS X) AppleV	1	1	33.6408064	-84.42564794	1		2
2/3/2016 8:44	2/3/2016 8:44	1	Mozilla/5.0 (iPhone; CPU iPhone OS 9_1 like Mac OS	1	1				ICAO building Montreal.	2
2/3/2016 13:48	2/3/2016 13:49	1	Mozilla/5.0 (Linux; Android 5.1.1; SM-G920V Build/L	1	1	37.0854194	-76.3777915	1		2
2/4/2016 15:13	2/4/2016 15:14	1	Mozilla/5.0 (iPad; CPU OS 9_1 like Mac OS X) AppleV	1	1	45.50042702	-73.56303313	1		2
2/4/2016 15:38	2/4/2016 15:40	1	Mozilla/5.0 (iPad; CPU OS 9_1 like Mac OS X) AppleV	1	1	45.50042702	-73.56303313	2	ICAO bldg in Montreal	2
2/4/2016 17:59	2/4/2016 18:00	1	Mozilla/5.0 (iPad; CPU OS 9_2_1 like Mac OS X) Appl	1	1	45.50042702	-73.56303313	1		2
2/4/2016 18:00	2/4/2016 18:01	1	Mozilla/5.0 (iPad; CPU OS 9_2_1 like Mac OS X) Appl	1	1	38.79005408	-76.69427984	1		2
2/4/2016 19:37	2/4/2016 19:38	1	Mozilla/5.0 (iPad; CPU OS 9_2_1 like Mac OS X) Appl	1	1				253 Millchurch Rd arnold md	2
2/4/2016 21:40	2/4/2016 21:41	1	Mozilla/5.0 (Linux; Android 5.1.1; SM-G920V Build/L	1	1	37.0526512	-76.3938875	1		2
2/6/2016 12:27	2/6/2016 12:28	1	Mozilla/5.0 (Linux; Android 5.1.1; SM-G920V Build/L	1	1	37.154236	-76.4604208	1		2
2/6/2016 16:47	2/6/2016 16:48	1	Mozilla/5.0 (Linux; Android 5.1.1; SM-G920V Build/L	1	1	37.0863858	-76.4725306	1		1
2/6/2016 22:33	2/6/2016 22:35	1	Mozilla/5.0 (Linux; Android 5.1.1; SM-G920V Build/L	1	1	37.0796762	-76.4727205	2	Jefferson avenue and Kingsv	1
2/8/2016 12:23	2/8/2016 12:23	1	Mozilla/5.0 (Windows NT 6.1; WOW64) AppleWebKi	1	1	41.4714088	-71.3940548	1		1

Figure F-3 WSPRRR Team GeoLocation Testing During Phase 1

#25 Participant Response Motivation

Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
Participant response motivation	4			3	3	3			3	3	0	0	12	12	12	0	0	12	48

- Condition:
  - Test deployments of the Low Boom Flight Demonstrator will be less than 1 month in duration. During this deployment it will conduct up to three flights on any given day with each flight affording two community exposures spaced at least 20 minutes apart. The Low Boom is intended by design to be unobtrusive and study participants will be exposed to them intermittently over this extended period of time.
- Departure:
  - It is expected that some portion of the participants will “drop out” due to distraction and fatigue.
- Affected Asset:
  - Subjective analysis requires a subjective response
- Consequence:
  - A statistically significant number of participant responses is required to support our analytical methods.
- Mitigation:

Reminders will be sent by text and e-mail to those who have not completed the single event survey within a predetermined period of time. At the end of the day an EOD survey link will be sent to respondent’s e-mail address, reminding them to complete the EOD survey. If they have not completed by a certain time frame (1 hour) they will be sent a reminder. Those who do not complete within a reasonable time frame after the reminder (4 hours) will be considered out of compliance with completion on that day and be marked locked out of the specific EOD survey so that they cannot complete it on a subsequent day. They will be still be eligible to continue in the study and will be sent a notification for the next survey. In the future, we have the ability to add an End of Night Survey if night time flights are included. If the respondent does not complete EOD within 1-hour, they will receive a follow-up reminder.

#26 Participant Recruitment Challenges

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
26	Participant recruitment challenges	3	4	1		3	4			3	3	12	3	0	9	12	0	0	9	45

- Condition:
  - The target for the QueSST would be 1000 respondents within the boom footprint in each of the six sites located in geographically distinct regions. Participants will be recruited from

communities under the flight path. The recruitment will include communities with a range of population densities selected from across the six regional geographic sites. We are asking Participants to serve as volunteers in support of this study during the course of their already busy lives.

- Departure:
    - It is possible that we may not get sufficient volunteers -
- Affected Asset:
    - Subjective analysis requires a subjective response
- Consequence:
    - If sufficient number of participants are not recruited then the statistical analysis of the subjective response will not be valid.
- Mitigation:

Once the target areas for boom analysis are determined and the demographic distribution of the community is assessed, we will sample from the population utilizing a targeted Address Based Sampling (ABS) approach. Address Based Sampling provides a high level of household coverage for representative sampling. Some estimate as high as 98% of the addresses of households in a community can be reached by ABS [Messer & Dillman, 2011]. ABS samples are based on the USPS Delivery Sequence File, which is regularly updated based on postal carrier reports. Vendors such as Survey Sampling International and Marketing Systems Group, through proprietary practices, append names, phone numbers and a variety of other factors (i.e. number of children) to addresses purchased. As many as 85% of addresses can be appended with the name of householder, and between 35 to 50% can be appended with phone number and additional information if additional contacts will be needed.

Towards a goal of reaching 1000 respondents that will complete the pre-survey and participate in the single-event and End of Day surveys, the recruiting strategy will utilize a Tailored Design Method [Dillman, Smyth and Christian, 2009] approach to 4000 homes in that targeted area. A complete enumeration of households will be conducted within a predetermined distance from installed noise monitors across the community. A random sample of households will be selected for recruitment using Address Based Sampling (ABS). In areas with sufficient population density, a systematic random sample will be selected by determining a random starting point on the enumerated list of available households and using a sampling interval. The interval would be based on the ratio of required respondents to the total number of available households in that area. For each household recruited, we would ask for the person over 18 years of age with the most recent birthday to identify the resident that would participate. The contact interview would ensure that the respondents both lived and worked in an area under the intended flight path. Respondents who complete an agreed upon percentage of all surveys will be eligible for a $25 incentive for each week of completion for a period of up to two weeks. The goal is to encourage participation with a small financial incentive, while being realistic about participant availability. The required completion rate to receive compensation may be based on the cumulative daily response rates to avoid situations in which the boom was presented but not perceived.

#33 Determination of Noise at a Participant's Location

	APS TEAM - COMPETITION SENSITIVE NNL14AA00C																			
	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
33	Determination of Noise at a Participant's location	4	0	0	0	2	0	3	3	3		0	0	0	8	0	12	12	12	44

- Condition:
  - NASA's objective is to understand the community response to sonic boom noise generated by low-boom supersonic aircraft. This requires correlation of the participant's response with the acoustic measurement of the low boom to which they responded.
- Departure:
  - Noise monitors will be deployed at fixed locations throughout the communities. Participants will not be constrained in their movements during this experiment.
- Affected Asset:
  - Correlation of sonic boom measurements with the subjective response (Where the participant is amongst the noise monitors)
- Consequence:
  - In order to correlate Noise Dose with response we must be able to determine where participants were when they experienced the low boom so as to determine which monitor(s) they were in the vicinity of. We anticipate some variation in the low boom across the community due to atmospheric turbulence, we must know which monitors the participant was nearest to in order to infer the noise dose that they experienced.
- Mitigation:

A combination of high-fidelity and low-cost monitors will be deployed in and around communities in the study area. Noise Monitors will be concentrated in the communities where we anticipate participants to be when the low boom occurs. A subset of sensors will be deployed across the carpet region so as to characterize the low boom across the region including the regional distribution of turbulence. If a participant hears a boom at a noise monitor's location (within 25 feet), then the metrics calculated from the monitor's recording will be used to define that participant's exposure for that event. In the likely case where this is not true and the participant reports hearing a boom further than 25 ft. away from the nearest noise monitors, then the estimate of the metrics at the participant's location will be determined based on a combination of first and foremost the noise measurements in the vicinity, secondly the statistical variance of turbulence across the carpet region and lastly predicted levels generated using PCBoom and the environment measured at the time of flight.

#8 Noise Monitoring Across a Large Carpet Region

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
8	Noise Monitoring across large carpet region	3	0	3	0	0	3	3	3	0	2	0	9	0	0	9	9	9	0	36

- Condition:
    - The QueSST Test Deployment will encompass a very large area (approximately 35x50 miles). This will entail deployment and control of approximately 100 noise monitors widely distributed throughout communities during the QueSST Test Deployment.
- Departure:
    - Noise monitors may be subject to theft or vandalization. The wide distribution of these noise monitors exceeds connectivity over WIFI or land line for operation and health monitoring.
- Affected Asset:
    - Low Boom acoustic measurement
- Consequence:
    - Reduced acoustic measurement of low boom to support Boom Analysis, generation of metrics for correlation with the subjective response.

- Mitigation:

The primary purpose of these measurements is to determine the noise dose provided to survey participants. A secondary purpose is recording the ambient noise and occurrence of atmospheric turbulence effects on sonic booms. Details of our approach to satisfy this objective are presented in section 6.4.1 of the Conceptual Test Plan. Secondary objectives include the following:

- Record sufficient data to assess sonic boom levels to correlate with potential complaints or damage concerns
- Understand non-low-boom sources that potentially cause participant response (misattribution to a sonic boom),
- Measure the full carpet of exposure including areas outside anticipated participant locations to document sonic boom levels,
- Evaluate land-based focus and climb sonic boom levels and extent,
- Conduct focus monitoring (placement avoidance success),
- Provide ambient data for monitoring locations for use in determining noise-dose.

In addition to the instrumentation described below it will be an important function that all personnel involved in the actual testing (LBDM & QueSST) to make a note of what they hear & observe; for example: did they hear 1 or 2 booms, what did they sound like, were you startled, was it calm or windy, A check list/log will be maintained by all personnel throughout the QUESST Test Deployment. This type info has been very useful in the past for determining where and when the booms were experienced in addition to resolving many questions relative to the nature of the measured signature (a sharp boom-boom signifies a peaked signature and a soft or muffled boom -boom would suggest a rounded signature). These would be secondary observations/measurements utilized to clarify those collected through instrumentation.

The QUESST Test Deployment will encompass a very large area, making the collection of accurate objective noise data with high certainty very difficult. Historically, sonic boom flight testing has demonstrated that loudness levels of traditionalN-wave boom signatures can vary on order 5-10 PLdB over distances of less than a half mile. Although low boom shaped signatures haven't been fully characterized with flight testing, it is anticipated that signatures may still vary by more than 3 PLdB over short distances, increasing the probability of high uncertainty in the objective data measurement.

Our team proposes a mixed-fidelity solution for collecting acoustic data to mitigate the cost burden of utilizing high-fidelity systems in very dense arrangement across the test site. The approach includes the WSPR 2011 sonic boom field kits, some new low cost noise monitors, and possibly some low fidelity sensors being studied in the FAA's ASCENT program. The following sections detail these monitors and their planned deployment for effective measurement of the low boom shaped signatures.

For the QueSST testing we recommend calculation of outdoor sonic boom metrics (Table F-3) as were computed in the WSPR 2011 testing [Page *et al.,* 2014]. The accuracy of noise monitoring systems across a range of metrics should be assessed to guide decision makers on future policy development. More recent discussions within the scientific and regulatory working groups hint that a hybrid metric may eventually emerge combining two or three traditional metrics, such as PLdB, dBA, dBC etc. Our mixed fidelity concept may provide additional insight into this process with a large dataset of correlated objective and subjective community data.

Table F-2 Outdoor Sonic Boom Single Event Metrics Recommended for the QUESST Regional Testing

METRIC LABEL	DESCRIPTION
PLdB	This is an estimate of Stevens Mark VII Perceived Level [Stevens, 1972] calculated using a time constant of 70 msec and averaging across the two peaks, which means 3 dB is subtracted from the 1/3 octave band levels calculated from the spectrum for the entire boom before the PL metric is calculated [Shepherd and Sullivan, 1991].
CSEL ASEL ZSEL dB	C-, A- and Z- Weighted Sound Exposure Level (SEL) values (time constant is 1 sec; there is no averaging).
LLZf LLZd dB	Zwicker loudness levels in phons, for frontal incidence and diffuse incidence, calculated using a time constant of 70 msec and averaging across the two peaks.
PNL dB	Kryter's [1959] Perceived Noise Level, calculated using a time constant of 70 msec and averaging across the two peaks.
maxpsf	Outdoors peak overpressure in psf.
iSone iPhon	Maximum instantaneous value of the Moore & Glasberg Time-Varying Loudness in units of Sones and Phons.
Av1Sone Av1 Phon	Maximum of the short term average value of the Moore & Glasberg Time-Varying Loudness in units of Sones and Phons.
Av2Sone Av2 Phon	Maximum of the long term average value of the Moore & Glasberg Time-Varying Loudness in units of Sones and Phons.

WSPR Sonic Boom Unattended Data Acquisition System

Sonic Boom Field Kits, were the primary sonic boom recording systems for the WSPR experiment. The field kits consist of National Instruments (NI) acoustic measurement and acquisition hardware and are controlled via NI LabVIEW software. Each field kit is comprised of a NI compactRIO (cRIO) hardware featuring a 9023 controller chassis, a 9234 Dynamic Signal Acquisition (DSA) module, 9870 RS232 module and 9401 digital I/O module. Other field kit components include a GPS antenna, two GRAS 40AN microphones with GRAS 26AJ LEMO preamplifiers, and a two-channel GRAS 12AQ signal conditioner/power module. The system is powered by a 105 Ah 12V deep cycle battery that is charged by a 120W solar panel. Systems can be built into environmental enclosures for protection, leaving microphones to be deployed on the ground inside GRAS 41AO systems providing waterproof windscreens and desiccant.

The combination of the NI hardware and the GRAS low-frequency microphones and preamplifiers make the SBUDAS high-fidelity noise monitoring equipment. Measurements can be made with 24-bit resolution at sample rates up to 51.2 kS/s, simultaneously sampled across the channels. Systems are time-synchronized by the GPS receivers.

The approximate cost of a single SBUDAS field kit is $12,000.

Low Cost Acoustic Instrumentation

A given QueSST Test Deployment will have a sonic boom carpet region that covers approximately 2000 square miles. In this carpet region there will be multiple communities with approximately 1000 participants distributed across them, requiring a significant number of noise monitors to ensure accurate determination of noise dose at or near a respondent's location. The SBUDAS high fidelity noise monitoring equipment utilized during WSPR 2011 cost approximately $12,000/unit; our assessment as described in section 6.4 of the Conceptual Test Plan calls for between 65 and 80 units for a QueSST Test Deployment we have initiated investigations into Low Cost Noise Monitors.

Commercial Off The Shelf (COTS) components have been identified that can be integrated to support Low cost monitoring systems able to obtain metrics within 0.1 – 1.0 PLdB. Such a system would consist of:

- Cellular phone – providing network capability and GPS for location and time synchronization
- Battery – with solar recharge capability for extended unattended operations
- Signal Conditioner
- Preamplifier
- Microphone

The signal conditioner and preamplifier could be integrated into a small electronic circuit board supporting 24 bit resolution for best dynamic range and a 48 kHz sampling rate. This could be integrated into a weather proof package for easy deployment as shown in Figure F-4. If the microphone must be located at ground level, when placed on soft earth, this package could be easily set below ground level with the microphone exposed on the surface. It is anticipated that grazing angle at the extents of lateral spread of the low boom will be a more significant factor than ground impedance.

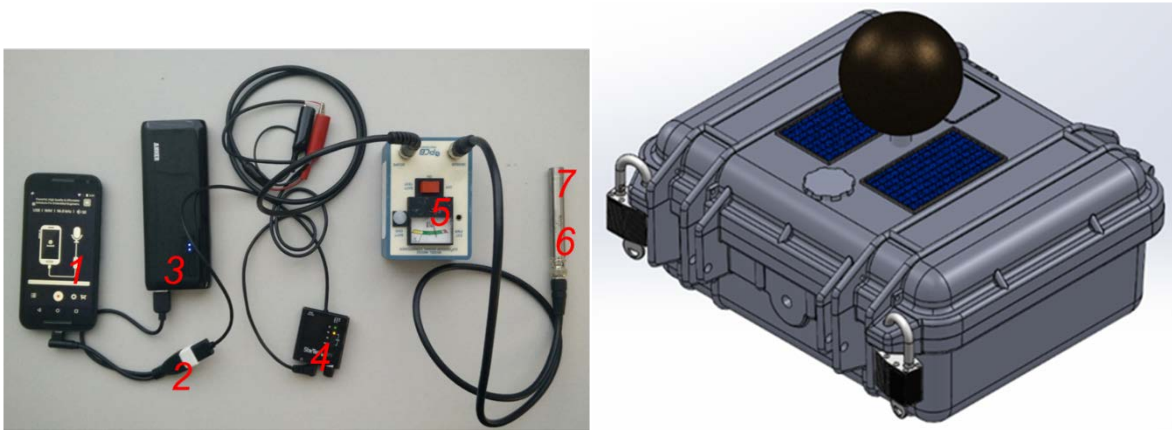


Figure F-4 Low Cost Noise Monitor Conceptual Design

For known flight times, the simplest option is to just record everything. From that we could determine causes of misattributed responses to non-booms. For non-flight times we would utilize these noise monitors on a periodic basis to determine local ambient noise levels.

#21 Cross Community Comparison

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
21	Cross Community Comparison	4	1	1	1	2	1	1	1	1	1	4	4	4	8	4	4	4	4	36

- Condition:
  - The QueSST experiment design is envisioned to occur over multiple sites over the course of a year.
- Departure:
  - Sites will present variation in climates, topographies, background noise levels, and demographics across the country.
- Affected Asset:
  - The goal of the community response test is to inform the regulatory community about the relationship between low boom noise dose and community response.
- Consequence:
  - To successfully inform the regulatory community will require a comparison of dose-response across communities to guide supersonic regulation development.

- Mitigation:

One of the key elements of a future QueSST sonic boom dose-response test design is ensuring adequate representation of the US general population, which includes diversity in the site selection process. Region and site selection also encompass a variety of operational concerns – from ensuring a representative sample of climate zones (and hence building construction types) found across the United States, to identification of an airport or base with sufficient runway length and facilities to support NASA QueSST operations, to determining flight tracks which meet the performance limitations of the QueSST while placing focus and climb sonic booms appropriately, to the identification of communities with the desired variation in demographics and building types. In order to ensure the total participant population and geographic areas selected are representative of the entire United States, sites were initially chosen from one of five climate zones (Figure F-5), as defined by Building America [Baechler *et al.,* 2013]. The climate zones are as follows; Cold, Marine, Hot-Humid, Mixed-Humid, and Hot-Dry. The Mixed-Dry and Very Cold climate zones were not used for site selection due to their relative small size and lack of large population areas. By selecting areas in each of these climate zones, we are able to represent a wide range of potential meteorological and atmospheric conditions, as well as community layouts and designs, building materials, and population densities.

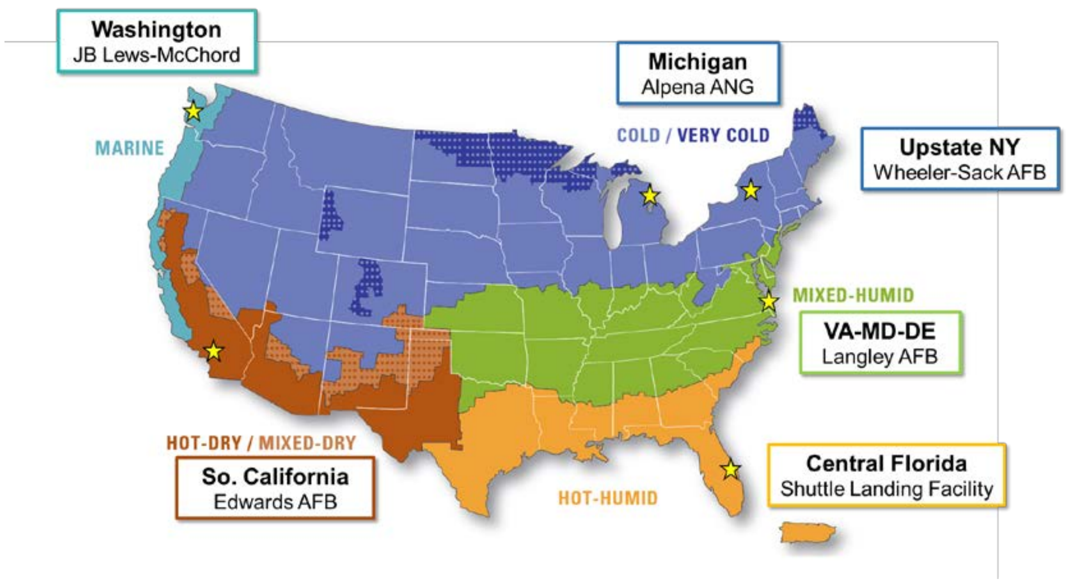


Figure F-5 US Climate Zones and Preliminary QueSST Test Sites

The development of our statistical design included consideration of other analysis approaches in noise research. We wanted to identify concepts that are distinct from our previous approach, but that could be applicable, and analyses that overlap and validate our approach. The "Information-criterion based selection of models for community noise annoyance" [Wilson, *et.al.* 2013] and the report on dose response relationships for overflight noise in Bryce Canyon National Park [Fleming, *et.al.* 1998] were both reviewed.

The review of "Information-criterion based selection of models for community noise annoyance" by Wilson *et al.* [2013] did identify methods that we had not used previously but could readily incorporate into our methods. The authors concluded that random slopes models are better than models with just a random effect for community assessment. The finding is supported by the perspective that communities will perceive noise differently because of their habituation to their environment, and this should influence the relationship not only with regards to an offset (intercept), but also in the functional relationship between annoyance and loudness (slope).

We have begun to assess the applicability of random slopes models for cross-community comparisons. Prior models [Wilson, *et.al.* 2013] have used this approach with the community tolerance level (CTL, the DNL at which 50% of survey respondents are highly annoyed) and community tolerance spread (CTS, the difference between the DNL at which 90% and 10% are highly annoyed). These community-specific adjustments are typically based on a measure of % highly annoyed. Because the low booms are lower in level, we anticipate the potential to have skewed data that clusters on the less annoyed end of the rating scale. However, we propose the use of this approach as a template that can be overlaid on any annoyance response data. That is, the data does not have to be highly annoyed data to utilize this method. This may additionally address concerns regarding our method for defining %HA in that it provides an established means by which we can evaluate our response data. The factors that contribute to the annoyance response vary within each individual and across individuals, as well as within each community and across communities. A dose-response model will be developed if this approach is supported by the data gathered. We plan to implement a comparison across communities using the above methods and others; for example, a simple χ^2 test can assess the relationship between noise measures and annoyance by counting the data in each cell for the number of responses (across communities) in each response category for each noise level. If we also produce these tables of counts separately within communities, this simple count data should be able to reveal the noise levels at which a shift in the subjective response is observed across communities.

We can incorporate this method, and may find a better statistical fit for the data. However, we need to be cognizant of our objective to identify a relationship between noise metrics and annoyance response that can be applied across different communities. If we find a significant random community slope component – then we'll know from the data analysis that there are functional differences in the perception of the noise from community to community. We anticipate observing such a difference when assessing noise impact in rural vs. urban communities, since the background noise will be significantly different in those two types of communities. Our site selection is purposely including such diverse locations so that are able to gather feedback from such distinctly different communities.

The introduction of using an information criteria approach for objective model selection and the conclusion that random slopes are likely the better statistical fit for the data are both concepts of merit that warrant consideration. The cited approach taken by the U.S. Army Engineer Research and Development center [Wilson, *et. al.* 2013] utilized the Akaike information criterion (AIC) [1974] which is a measure of the quality of a statistical model compared to other models for the same set of data. Another model selection approach, the Bayesian information criterion (BIC) [Burnham, *et.al.* 2002] is based partially on the likelihood function. When applying likelihood you are given the outcome and use it to describe the function of a parameter. In contrast, with probability you are given a parameter, and use it to describe a function of the outcome. The BIC is closely related to the AIC [Burnham, *et.al.* 2002].

As applicable, we could also evaluate if these same findings hold under the use of BIC as opposed to their AIC methods. The method of Maximum Likelihood (ML) maximizes the agreement of a model with the given data set. We could also experiment with the use of Restricted Maximum Likelihood estimation, or REML. REML is a method used in fitting linear mixed models. Since AIC is known to over fit the data, and BIC is asymptotically consistent (and it seems as though their sample sizes are large), BIC might choose simpler models. REML avoids ML estimates living outside of the parameter space. It often has no impact at all, but in the rare case when the ML estimates do live near the boundary or outside of the parameter space, REML fixes the problem. In this specific example, though, given the magnitude of changes, it is unlikely that the use of REML and/or BIC would reach a different conclusion, but it would be interesting to explore.

In the report on dose response relationships in Bryce Canyon National Park by Fleming *et al.*, the data analysis models were simple logistic regressions predicting the dichotomous annoyed/not annoyed response (which was not the percent highly annoyed/not highly annoyed), which we used in WSPR. The analysis methods they employed were similar to those we have proposed. Our rural locations should provide sufficient opportunities for a quieter background that those rural findings could be used to infer the annoyance perception in the quiet environment that is typically found in national parks.

The park study used special acoustic equipment designed to measure very low-level ambient noise, because the background noise levels were rather quiet. The report emphasized the importance of including a wide range of noise doses in order to adequately assess the response, and given that their respondents were in a very quiet environment, they determined that if a participant didn't report hearing the aircraft, they weren't annoyed. Since background noise in our study can vary based on the participant's activities at the time of the boom, and the relatively louder background noise in a community compared to a park, we cannot assume that a non-response is equivalent to a response of "not annoyed" if the boom were audible. In our case the perception of the boom may be masked by respondent activities or other environmental noise. For our effort, if an individual does not respond, we can tally that data as "non-response". We will be using text messages to prompt attentive listening, to keep respondents focused on the listening task.

#23 No Subjective Response

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	***Total Impact Across Design***
23	No Subjective response (Participants didn't hear it)	4				3	1			4	3	0	0	0	12	4	0	0	16	32

- Condition:
  - o Low Boom delivered will be very quiet, barely above background noise
- Departure:
  - o Participants may not notice the boom or could confuse it with background noise therefore not responding when it occurs
- Affected Asset:
  - o Subjective analysis requires a subjective response
- Consequence:
  - o If participants do not respond to the low boom when it occurs it is important to our analysis to understand why they did not respond, for example:
    - ▪ Were they beyond the range of the low boom?
    - ▪ Were they listening attentively
    - ▪ The low boom was not discernable above the background noise?

    - They were indoors and the low boom did not propagate into the structure

- Mitigation:

We will include the use of text push messages that states: "Please remember to listen for a boom" to encourage attentive listening. There will be instances where we will present a boom within 30 minutes, and other times we will send the text reminder with no subsequent boom. This design allows us to assess if the response is due to the text prompt or because the respondent heard a boom. The text prompt is included in the design in an attempt to address concerns about non-response. A non-response would occur if a respondent truly didn't hear a boom (not loud enough) or if they weren't listening (not responsive). Another alternative is to send a post-boom text that asks "Did you hear a boom?" This approach relies on the respondent's memory recall of the past 30 minutes. With this approach, there is a potential risk of mistaken recall. We would prefer to prompt attentive listening, than rely on memory recall. We can conduct a comparison test of the two approaches in the Risk Reduction test.

Reminders will be sent by text and e-mail to those who have not completed the single event survey within a predetermined period of time.

Any text messaging that takes place will need to conform to the FCC's Telephone Consumer Protection Act (TCPA). This includes that consent to text must:

- Be in writing
- Come from the owner of the device where texts will be received
- Identify any parties that will have access to the respondent phone number
- Make clear the type of messages that will be sent
- State the costs or potential cost to the respondents

Include information on how to opt out of the messaging

#1 Transition Focused Footprint

	Risk Title	***Prob***	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	***Total Impact Across Design***
1	Transition Focused Footprint	1	4	5	5	2	3	3	5	3	4	4	5	5	2	3	3	5	3	30

- Condition:
    - Transition Focused footprint is unavoidable as the QUESST transitions to supersonic.
- Departure:
    - Possibility of the focused footprint overlapping the Participant community.
- Affected Asset:
    - Subjective Response
- Consequence:
    - Encroachment of the focused transition boom over the community could elicit a subjective response to more intense focused boom verses low boom.

- Mitigation:

The placement of potential focus booms is a major component of the site selection and flight operation procedure. Turn focus may be avoided by reducing to subsonic speeds following a sonic boom community pass and exposure while positioning the aircraft for any subsequent flight passes. Using aircraft performance information and the PCBoom software suite, approximate pressure contours have been modeled and plotted under the proposed flight paths to determine if and where focus booms might exist. One of the important criteria in site selection is proximity to large bodies of water and/or sparsely populated areas, precisely for the purpose of placing focus booms away from large communities. In most cases a steady climb to cruise altitude occurs after the transition focus region. This futher insures that the focus region is located well uptrack of the test community.

Focus booms may or may not occur due to turns depending on the parameters of each maneuver, which can be modeled in PCBoom to determine if a focus exists. If the flight path requires turn over a populated community, the aircraft must be decelerated below supersonic to avoid any boom altogether. This will necessitate another acceleration from subsonic to supersonic speed with its unavoidable transition focus boom region followed by the climb to cruise condition. Figure F-6 illustrates to scale a climb transition focus to climb to cruise sonic boom footprint and overpressure levels for the Hot-Humid Region for a westbound flight based on notional aircraft performance attributes. The subsonic to supersonic transition focus is the higher amplitude (psf) contours on the eastern portion of the footprint. And nominal cruise conditions are achieved at the eastern seaboard. During detailed operational deueUESST aircraft flight performance capabilities.

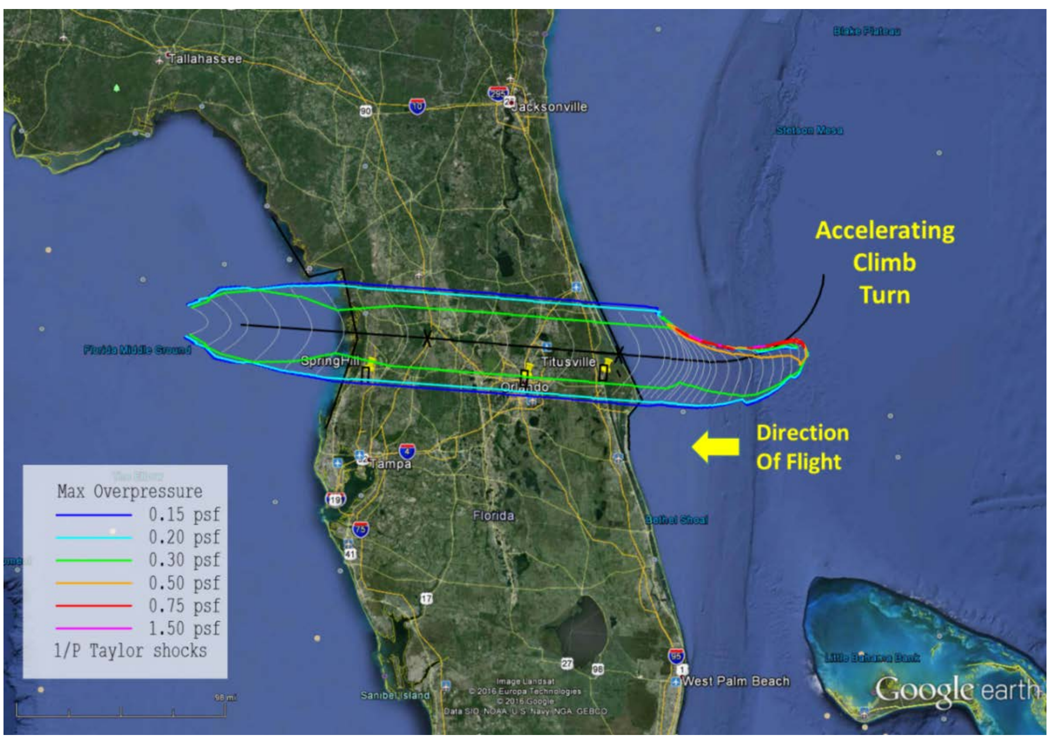


Figure F-6 Climb Acceleration Flight track, Focus & Carpet Sonic Boom Footprint, Hot-Humid Region

#2 Climb Boom Footprints

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
2	Climb booms	1	4	5	5	2	3	3	5	3	4	4	5	5	2	3	3	5	3	30

- Condition:
  - For the ultimate production vehicle, a the aircraft climbs to its cruise altitude a series of shaped booms are anticipated under the flight path before the beginning of the carpet region, as seen in Figure F-7. The LBFD might not have a minimized low boom signature in the climb region.

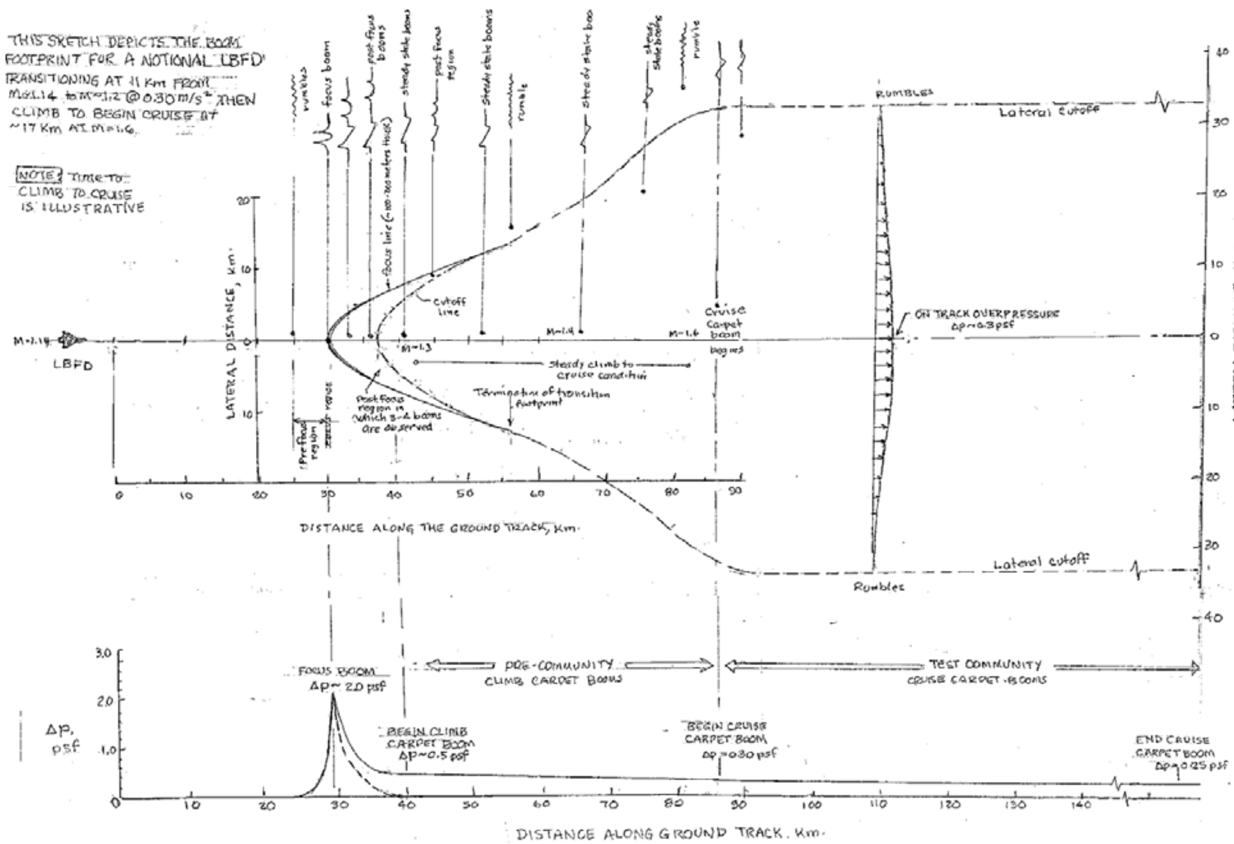


Figure F-7 Boom footprint for a Notional LBFD transitioning at 11 km from Mach 1.4 to 1.2 at 0.30 m/s^2 then climb to begin cruise at 17 km at Mach 1.6 , Domenic Maglieri 2015

- Departure:
  - Possibility of a non-optimized low-boom footprint overlapping the Participant community.
- Affected Asset:
  - Subjective Response
- Consequence:

  - o Encroachment of either a non-optimized low boom signature or a focused transition boom on the community could elicit a subjective response to more intense focused boom instead of the low boom.
- Mitigation:

Using aircraft performance information and the PCBoom software suite, approximate pressure contours have been modeled and plotted under the proposed flight paths to determine if and where climb booms might exist. PCBoom V6 can model varying source characteristics during climb boom based only on changes in Mach number. For examination in the future of optimized climb profiles this capability will need to be expanded to include additional parameters such as thrust, lift coefficient and trim state. Given that the climb region occurs in the area just preceding the carpet region noise monitors would be placed at the land/sea transition or across the flight path preceding the carpet region to ensure that shaped booms associated with the climb region do not encroach upon communities in the carpet region as shown in Figure F-8.

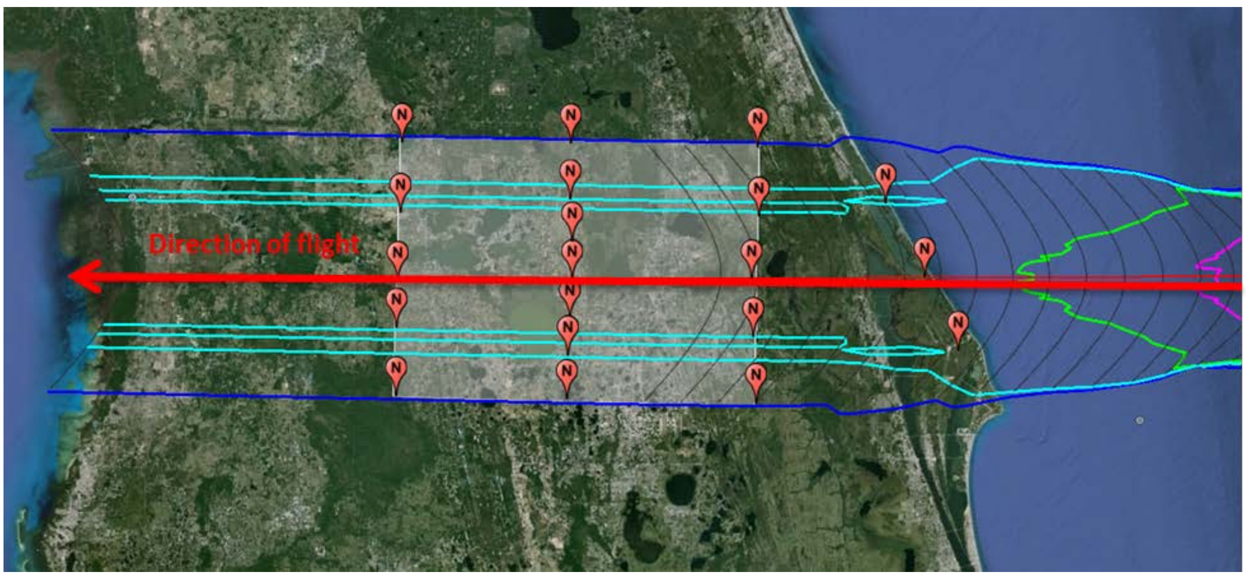


Figure F-8 Flight Path Carpet Region Instrumentation Requirements

(The three easternmost sensors are intended to verify that there is not any encroachment of the focus/climb booms upon the carpet region.)

#30 Flight Trajectory Precision

	Risk Title	***Prob***	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	***Total Impact Across Design***
30	Flight Trajectory Precision	2	3	3	1	1	1	1	3	2	2	6	6	2	2	2	2	6	4	30

- Condition:

  - o The focus and climb region footprints and signatures generated by the QueSST aircraft are anticipated to be highly sensitive to the flight trajectory.

- Departure:
  - o Slight variations in flight trajectory can result in significant changes in the boom footprint and signatures as shown in Figure F-9.

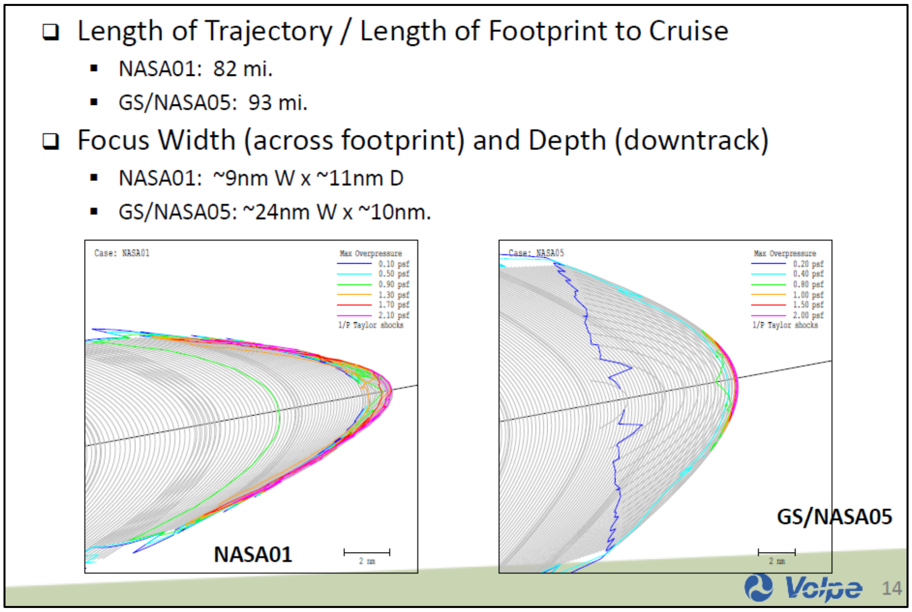


Figure F-9 Footprint sizes for two different hypothetical trajectories

- Affected Asset:
  - o Prediction and accommodation of unavoidable focus boom
- Consequence:
  - o Inability to accurately predict the low boom footprint could result in misplaced focus boom possibly encroaching upon the subject community
- Mitigation:

The LBFD aircraft onboard instrumentation requirements to support the dose-response testing should include at a minimum:

- GPS time synchronized positional information
- Mach meter with sufficient precision/response from which Mach rate and second derivatives can be determined
- Aircraft orientation (roll, pitch, yaw) with sufficient precision/response from which first and second derivatives can be determined
- Propulsion system operating state information from which low-boom source characteristics can be determined (especially during climb and acceleration and turning maneuvers which could result in focused booms)
- Aircraft trim information – either primary or derived, from which low-boom source characteristics can be determined

Modeling the flight, with tools such as PCBoom supports definition of the proper trajectory to ensure accurate placement of the focus and climb boom footprints in the area selected to accommodate it. Possible differences between modelled and measured data may include variation in the aircraft data (e.g., tracking, attitude, source characteristics etc.) and weather (i.e., the modeled atmosphere versus what exists at the time of flight).

Current modelling relies on several approximations – all of which will need to be revisited as the LBFD design is refined and built. The approximations used in Figure 10 include:

- Vehicle cruise source characteristics are based on the NASA LBFD Design [Ordaz et al., 2015]
- Climb profile is based on nominal aerodynamic characteristics developed by Gulfstream and assumed engine performance margins.
- Off-design source characteristics were not utilized in the analysis presented here. In the future off-design characteristics can be modeled in PCBoom[††] via CFD analysis and cylinder inputs based on the LBFD vehicle climb profile Mach, C_L and trim.

#22 Low Boom Signature is a New noise Source

	Risk Title	***Prob***	**#1 Site Logistics Consideration & Selection**	**#2 LBFD Parameters, Focus Booms & Flight Ops**	**#3 Communications and Outreach**	**#4 Survey and Dose Response**	**#5 Survey Implementation and Recruitment**	**#6 Noise Measurements**	**#7 Boom Analysis**	**#8 Data Analysis**	**Average**	**#1 Site Logistics Consideration & Selection**	**#2 LBFD Parameters, Focus Booms & Flight Ops**	**#3 Communications and Outreach**	**#4 Survey and Dose Response**	**#5 Survey Implementation and Recruitment**	**#6 Noise Measurements**	**#7 Boom Analysis**	**#8 Data Analysis**	***Total Impact Across Design***
22	low boom signature is a new noise source	4			1	2	3			1	2	0	0	4	8	12	0	0	4	28

- Condition:
  - Shaped low boom signature will be a new noise source, unfamiliar to the community.
- Departure:
  - New sound sources could have a greater impact upon subjective response due to subjects being unaccustomed to them rather than due to their intensity (a quiet but unfamiliar sound could be more unsettling to a subject than a louder sound with which they are familiar).
- Affected Asset:
  - Subjective response
- Consequence:
  - We are seeking to identify an acoustic metric that can be correlated with a subjective response, when in fact the subjective response will be due in some part to the fact that the sound is unfamiliar.
- Mitigation:

Simulator Days: Use simulator to introduce/train a portion of the participants on low booms. We plan

[††] PCBoom V6 can model varying source characteristics during climb boom based only on changes in Mach number. For examination in the future of optimized climb profiles this capability will need to be expanded to include additional parameters.

to conduct an orientation effort using the Gulfstream Aerospace SASSII simulator [Salamone *et al.*, 2005] to introduce respondents to the sound character of a low boom and train them on the range of low booms to be presented. Familiarization with the sound character and potential levels of low boom events will help respondents to better recognize booms, and distinguish them from other similar sounds. Research based materials would be developed for this Simulator Days familiarization period, to introduce the concepts behind the field test. This would include descriptors such as comparing the low boom noise to distant thunder or two car door slams in succession. The team would need to keep a record of which participants heard the range of booms in the simulator. Our approach would not widely advertise the familiarization period, but it would allow any interested parties to join in. This affords the opportunity to provide auditory exposure and training to allow the respondents to identify sound character and range of booms.

#17 Media Response

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
17	Media Response	3	3		3					3	3	9	0	9	0	0	0	0	9	27

- Condition:
  - In today's public digital media environment opposition groups can be more easily formed and negative media content can rapidly spread
- Departure:
  - Rapid spreading of negative media announcements can influence subjective response
- Affected Asset:
  - Subjective response
- Consequence:
  - Media coverage, either positive or negative, could raise a question of our biasing the respondents, and potentially cast doubt on the integrity of our research findings.
- Mitigation:

We are cognizant that this test is being conducted for regulatory review, and as such, are taking additional precautions with our Outreach planning and the conduct of our Outreach efforts to ensure the validity of our research findings. As part of our site selection process we will identify activist communities with anti-Government tendencies as identified through social media, bloggers, online websites etc. Local Media outlets including News Stations, Radio, State, Regional and town newspapers and online publications will be identified by the WSPRRR team in advance of the Flight Test. During the last quarter before the flight test the NASA public affairs office will verify that communication lines are open with these organizations to ensure they can be readily accessed in the event immediate press releases need to be made during the test execution. Potential partners for outreach and points of contact will be identified. These might include colleges and universities in the region as well as libraries, schools, museums, science centers (Table 2-4). As described in the Community Engagement and

Outreach Section (Section 3) outreach will only begin after the flight testing has been concluded.

Coordination with the FAA will be the responsibility of NASA. This coordination will include obtaining necessary airspace supersonic flight authority and other airspace logistics regarding flight operations. Preliminary discussions with the FAA will be approximately 1 year in advance of each Regional Flight Test. Final airspace requirements will be identified by NASA based on the flight operations portion of the test plan for each region. These will be determined jointly by NASA and the WSPRRR team at least 6 months prior to test execution. It is likely that the LBFD manufacturer is also involved in the operational flight design.

Prior to the flight test, social media monitoring will be conducted as described in Section 8.6. The timing of this will be as recommended by the ASCENT program researchers, however it is expected there will be two periods of monitoring – one period at least 2 quarters prior to the flight test and a second period within the quarter immediately preceding the test. This will allow for the establishment of baseline levels prior to the LBFD test and permit researchers to identify subtle regional characteristics related to this subject area.

The WSPRRR plan initiates a more subtle Outreach approach prior to the test, with a media based outreach effort after each Regional field test has been completed. This approach advocates maintaining a low profile initially to avoid large media coverage and the introduction of bias. The test objective is to gather data to support regulatory review, and the proposed design considers the potential impact of media coverage on our data gathering process and how our findings are viewed. Positive media coverage could bias respondents, and could also be misconstrued as an attempt by our team to bias research participants to respond more positively. Negative media coverage could bias our respondents, and could result in potential community based objections that could delay the flight test. As such, we are delaying full media coverage until after the test. The information provided initially will consist of research test based content.

#18 Startle or Rattle

	Risk Title	***Prob***	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	***Total Impact Across Design***
18	Startle or rattle	3	0	2		3				3	2	0	6	0	9	0	0	0	9	24

- Condition:
    - LBFD is designed to produce a low boom on the order of .3lbs/ft2, however it can still induce rattle or startle. Startle is a subjective response and rattle effects occur most often indoors.
- Departure:
    - Our plan for outdoor acoustic measurement of the sonic boom and will not provide objective measurements associated with rattle.

- Affected Asset:
  - Subjective response
- Consequence:
  - Startle or rattle could influence the subjective response
- Mitigation:

While we do not propose direct objective measurement of startle or rattle we will attempt to capture information regarding it through careful survey design to include questions such as:

E8 How much did the sonic boom **startle you** or **make you jump**?

(Not at all) 0 1 2 3 4 5 (Extremely)

E9 Vibration is a motion. The motion may be seen or felt. How much **vibration** from the sonic boom did you see or feel?

(Not at all) 0 1 2 3 4 5 (A great deal)

E10 Rattle is a type of noise that can occur when objects move due to a vibration. How much **rattle** from the sonic boom did you experience?

(Not at all) 0 1 2 3 4 5 (A great deal)

Additional mitigation activities proposed could include instrumentation of local government/public buildings to assist in the assessment of internal rattle.

The data can be evaluated using Tau-b non-parametric categorical analysis methods assessing the strength of the dependence between the annoyance responses and contributing categorical variables such as rattle or vibration.

#20 Sleep Disturbance Complexity

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
20	Sleep Disturbance Complexity	3	0		2	3				3	2	0	0	6	9	0	0	0	9	24

- Condition:
  - The LBFD is designed to support night flights
- Departure:
  - Night flights of LBFD may cause awakenings or sleep disturbance..
- Affected Asset:
  - Subjective response
- Consequence:
  - Sleep disturbance includes the inability to go back to sleep. We can monitor awakenings (the boom woke them up). The inability to go back to sleep has more components than just noise, and adds complexity.

- Mitigation:

It was stated by NASA at the Kickoff meeting that the additional complexity of studying sleep disturbance is beyond the scope of this field test. Sleep disturbance is not included in the scope of this test plan and will require a separate substantial effort. Awakenings by participants who go to bed before the last flight or who might sleep during the days (i.e. night-shift workers) will not be included in this test plan. It is possible that working nights could be potential disqualification grounds during recruitment; however this has not yet been finalized. The design of the flight times (in progress) will also take this into consideration. For the LBFD test, there should be no sonic booms after 9 pm local time.

#28 Low Frequency Building Excitation

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	***Total Impact Across Design***
28	Low frequency building excitation	3	2					3		3	3	6	0	0	0	0	9	0	9	24

- Condition:
  - The LBFD signature includes low frequency energy
- Departure:
  - Low frequency energy could excite large buildings
- Affected Asset:
  - Subjective response
- Consequence:
  - Experience has shown that sonic booms of 1 -3 PSF from supersonic flights over communities have resulted in damage claims. Reported damage has included mostly brittle surfaces and secondary structural components. Results from the St. Louis overflight tests showed that no damage incidents occurred from booms of less than .8psf.
- Mitigation:

As shown in Figure F-10[Maglieri et. al. Six Decades, 2014] the low intensity and shaped signature associated with the LBFD is not anticipated to significantly affect structures. Instrumentation of a local government/public building could assist in assessing these effects.

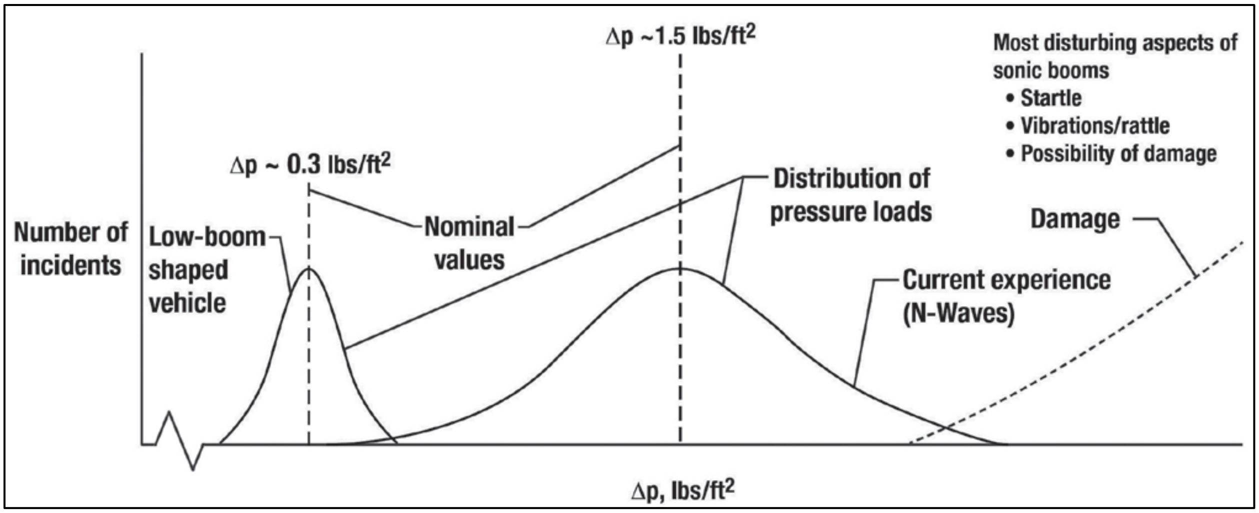


Figure F-10 Nature of sonic boom induced damage

#32 Geolocation through Qualtrics

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
32	Geolocation through Qualtrics	4	0	0	0	0	3	0	0	3		0	0	0	0	12	0	0	12	24

- Condition:
  - The location from where a person responds will be noted if they respond through the Qualtrics APP
- Departure:
  - The person may respond after the boom from a different location other than where they heard it
- Affected Asset:
  - Subjective response/Data Analysis
- Consequence:
  - The location associated with the subjective response may be offset from the location where the respondent was when they experienced the boom causing difficulties with the correlation with objective measurements.
- Mitigation:

The survey design will include confirmation of where the person was at the time of they experienced the low boom.

#24 FAA Activity Conflicts

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
24	FAA Activity Conflicts	1	4	2	3	4	3		3	3	3	4	2	3	4	3	0	3	3	22

- Condition:
  - FAA is changing flight paths (Metroplex) unrelated to supersonic flight
- Departure:
  - LBFD flights could occur near communities that are newly exposed to aviation noise due to implementation of Metroplex
- Affected Asset:
  - Organizational Conflicts
- Consequence:
  - Community members where flight paths have recently changed may be more sensitive to aviation noise in this time period.
- Mitigation:

Be cognizant of metroplex locations for site selection and test implementation; include question on sensitivity to noise on background survey; pay closer attention to noise background for boom analysis.

#13 Structural Damage NOT due to the LBFD

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
13	Structural Damage not due to LB	2	0			2	4		4		3	0	0	0	4	8	0	8	0	20

- Condition:
  - Condition of structures will vary within the Participant community
- Departure:
  - Structures in need of maintenance my suffer damage through normal wear and tear which could be incorrectly attributed to the low boom
- Affected Asset:
  - Subjective response
- Consequence:
  - Damage which occurs could result in a negative Subjective perception, even if it was not caused by the LBFD
- Mitigation:

Identify highly unique construction ahead of the experiment and conduct an assessment to establish a baseline prior to the experiment. Include questions in baseline survey on house construction type. Evaluate prior to the experiment utilizing modelling and simulation

#14 Boom Level Enhancement Through Structural Structural Configuration

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
14	Boom level enhancement through structural configuration	2	0			2	4		4		3	0	0	0	4	8	0	8	0	20

- Condition:
  - Open V structures (boom enters the open part of the V) and three corner structures (i.e. overhangs) may exist in the Participant community.
- Departure:
  - Incident boom level could be enhanced from 2-8 times depending on the ground configuration
- Affected Asset:
  - Subjective response
- Consequence:
  - Damage is unlikely (see Risk 28), however if a participant is standing in the wrong place they may experience increased boom levels over what was predicted or concluded through acoustic analysis
- Mitigation:

Identify these structures in the experiment area before hand and install noise monitoring to assess enhanced incident boom levels.

#4 Turbulence Allowances for Noise Dose

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
4	Turbulence Allowances for Noise Dose	2	1			2		3	3		2	2	0	0	4	0	6	6	0	18

- Condition:
  - Atmospheric Turbulence (micro effect) distorts boom signatures (increase or decrease the PL) and makes it difficult to determine the OBJECTIVE Dose at the Participant locations
- Departure:
  - Possibility of turbulence causing spiking/rounding in the signatures and louder/quieter than anticipated boom levels
- Affected Asset:
  - Noise Measurement/Boom Analysis
- Consequence:
  - Noise predicted may not reflect noise experienced

Mitigation:

Include as part of the Site Selection Process a review of historical climatological data with respect to atmospheric condition that are known to contribute to turbulence. Measure/quantify turbulence affect through array clusters arranged in the Participant community. All mic stations must have at least 2, and more like 3-5mics spaced at least 100 ft. apart in an "L" or"cruciform" layout. Two mics 100 ft separated will indicate whether turbulence is present. Additionally we may leverage SonicBAT accomplishments to better characterize the distribution of turbulence throughout the carpet region.

Atmospheric Turbulence are anticipated and given our mitigation strategies we consider the probability of not making correct allowances for the Objective Dose to be low but not non- existent (2). This is of consequence to our Site Selection process (1) in that we will include consideration of historical/climatological atmospheric conditions which could contribute to turbulence as part of our process. Given the intermittent and small areas over which turbulence can create an impact the consequence to Survey and Dose Response is considered low (2). We will need to consider the number and configuration of microphones necessary for turbulence detection with respect to Noise Measurements (2) and ensure that our Boom Analysis does make the necessary allowances for the objective dose (2), both of which have been successfully accomplished during WSPR 2011.

We expect much less distortion of the shaped signature due to the micro influences (turbulence) of the atmosphere since the signature is designed to have less energy at the high frequencies. Shocks are made up of high frequencies, N-waves have a lot of high frequencies, and that is why they get distorted seriously by turbulence. The basic premise behind designing a a/c with a low boom shaped signature (lots of shock rise time) is two fold, first it must be a softer boom by reducing the signatures high frequencies to gain community acceptance. The lowering of the high frequencies should make the signature less susceptible to the influence of atmospheric turbulence.

#5 Diurnal Effect

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
5	Diurnal Affect	2	1	2		2		2	2		2	2	4	0	4	0	4	4	0	18

- Condition:
  - The diurnal change results from heating of the land causing a change to the atmospheric profile above it
- Departure:
  - This is a macro effect which can result in change in the boom footprint; this diurnal change can additionally be a source of atmospheric turbulence in the lower layer of the atmosphere resulting in distortion of the boom signature.
- Affected Asset:
  - Noise Measurement/Boom Analysis
- Consequence:
  - Acoustic analysis may not correctly provide noise level for correlation with a Subjective

perception

- Mitigation:

As stated in Section 6.2, it is expected that a wide variety of weather conditions will be encountered over the course of the LBFD test deployments. The aircraft will be designed to fly in variable conditions and in fact analysis over a wide variety will only strengthen the analysis. The key here is sufficient environmental monitoring to support analysis of the low boom delivered.

The influence of the atmosphere on propagation of sonic booms can be defined in terms of the macro and micro effects; macro being associated with the effects of pressure, temperature and wind profiles and micro effects being associated with turbulence, especially in the first few thousand feet of the earth's atmosphere [Maglieri *et al.,* 2014].

Macro effects will result in refraction of sonic boom energy as they propagate to the ground resulting in variations in sonic boom strength and/or its footprint. The upper atmosphere must be monitored so that its affect can be analyzed through the use of PCBoom; for example: The assessment of the planned flight trajectory to ensure delivery of the proper noise dose across the subjective communities on the day of flight. These measurements will additionally be utilized to support post flight analysis to more precisely (spatially and temporally) determine the noise to which participants responded.

The turbulent process in the atmosphere (micro effects) is the result of some form of instability that produce random fluctuations; these translate to signature distortions at different points across the boom carpet. In most cases there is a diurnal effect observed where in the morning a quiescent period occurs, followed by increasing turbulence corresponding with solar heating through the course of the day. Atmospheric turbulence are difficult to directly measure though their presence can be indicated through surface measurements of the atmosphere and acoustic measurements of the variability of the boom signature. Monitoring these atmospheric conditions during the flight will support post flight analysis in accounting for any spikes or rounding of the boom signature in the measurements.

During WSPR 2011 the F-18 waypoints required in the execution of a low boom dive maneuver were calculated on recent GPS rawinsonde upper air meteorological data as well as an assessment of the best flight cards to be flown depending on the atmospheric conditions over the single community surveyed. Additionally two ground based surface weather instrumentation systems were utilized to collect atmospheric pressure, temperature, relative humidity, wind speed and direction at a 1 Hz rate [Page et al., 2014]. The primary differences between the approach utilized during WSPR 2011 and what is required for the LBFD experiment are:

3. WSPR 2011 was conducted over a single community (approximately 3 square miles) whereas the LBFD experiment will include a carpet boom region of approximately 50 miles in length and 35 miles in width (1750 square miles).
4. F-18 waypoints in the execution of a low boom dive maneuver will not be required. The LBFD will fly at a constant altitude over the carpet boom region. It is anticipated that one or more GPS rawinsondes will be required to refine the trajectory flown across this region.

The size of the low boom carpet region mandates maximizing the use of existing meteorological infrastructure for the collection of data across such a region as well as complimenting it with low cost sensors deployed in the communities being surveyed as well as the use of high resolution numerical weather modelling to support post flight analysis (see 9.1.4).

The existing meteorological infrastructure includes National Weather Service data feeds (Text, RSS and XML) providing observed current weather conditions for about 18,000 locations across the United States. Aviation Weather Products available for download and archive include:

- METARS – surface weather observations issued hourly
- Aircraft Reports – Aviation weather provided from transiting aircraft
- TAFS – Terminal Aerodrome Forecasts issued every six hours from major civil airfields
- AIR/SIGMETS – Significant weather conditions distributed by the National Weather Service as they develop

A review of our Florida example under consideration indicates that 17 sites could support archival of surface weather observations (Figure F-11).

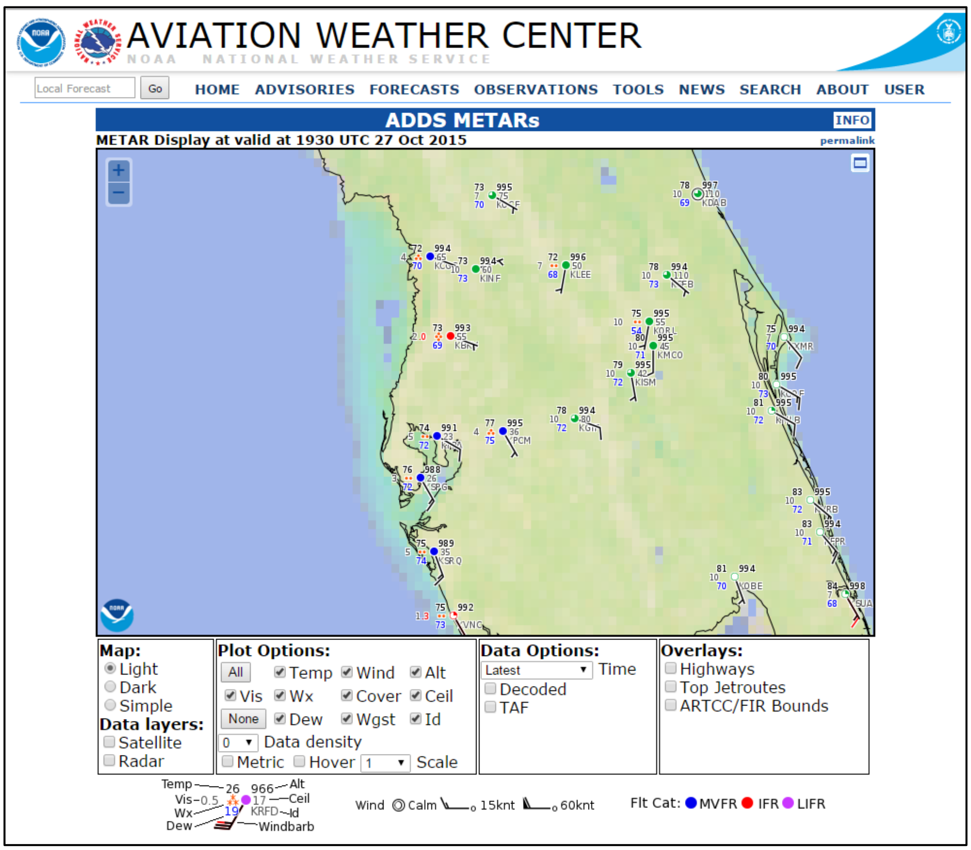


Figure F-11 NOAA METAR Observation Sites Available for Data Archive Between Orlando and Tampa

The limitations of NWS resources are that they provide periodic updates from fixed locations which may not be suitable for all of the sites currently under consideration. It is advised that a small number of self-contained commercial weather stations be installed in the center of each community across the survey area. The advantage of deploying these systems is that their continuous measurements can be most accurately correlated with the time of the boom at a given location. Additionally these systems distributed across the communities in the carpet region would provide an indication of near surface turbulent conditions for correlation with noise measurements in their vicinity. These monitors would additionally provide specific observations that could be used as inputs to high resolution numerical weather predictions; and finally they would provide an absolute source of surface atmospheric conditions over which the analysis team has direct control. Weather stations such as the Davis Instruments 6250 (Figure F-12) support an IP interface allowing these to be integrated into the Noise Monitoring Network for real time monitoring as well as archival of atmospheric data at each site for post experiment analysis. These instruments retail for $500; if one weather station was deployed in the center of each community the resulting cost to the experiment would be approximately $3000-$4000.

Figure F-12 Davis Weather Station (6250)

Upper air soundings are far less available through the existing meteorological infrastructure. The National Weather service collects upper air soundings twice a day (up to an hour before 00:00 and or 12:00 UTC) at 69 locations in the continental United States (Figure F-13). These are intended to support regional weather forecasts. Specific observations associated with these sites are available in a number of formats going back to 1946 [NOAA/ESRL Radiosonde Database]. These are not likely sufficient to support “Day of Flight” planning, however they could be useful in characterizing the elevated atmospheric conditions associated with candidate sites.

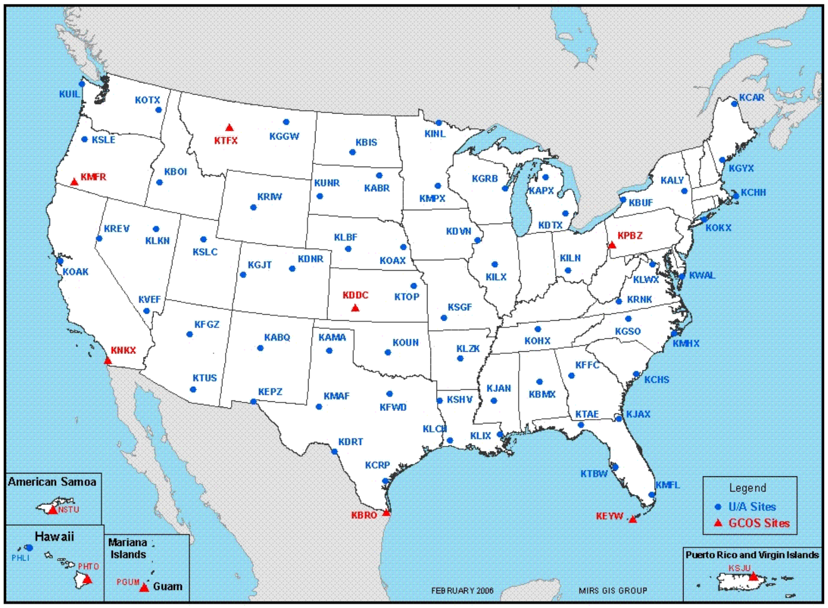


Figure F-13 Upper-Air Network; GCOS – Global Climate Observing System

(http://www.ua.nws.noaa.gov/nws_upper.htm)

On the day of flight NASA resources will be relied upon for the collection of upper air data. Atmospheric soundings should be made simultaneously along the length of the trajectory. These measurements shall be made in accordance with NASA protocol and procedures. It is anticipated that measurements will be made prior to the first flight and thereafter as dictated by changing weather conditions. The distance interval between soundings will depend upon the site. Were the study area to traverse a mountainous area as would be found in Colorado or some other location with distinct weather patterns created by a geographic feature, then rawinsondes would need to be launched in each of these areas. In the case presented in Figure 6-13 where the study area spans the width of Florida, soundings would be made simultaneously at the beginning, mid-point, and end of the trajectory. If the focus zone and/or the climb region are on land, additional measurements should be made in each of those regions as well; otherwise a measurement should be made at the land/sea interface. It should be noted that atmospheric soundings accomplished through the use of “weather balloons” are neither instantaneous nor true vertical measurements. The NOAA National Weather Service Fact Sheet for Radiosonde Observations notes “A typical NWS "weather balloon" sounding can last in excess of two hours. In that time, the radiosonde can ascend to an altitude exceeding 35 km (about 115,000 feet) and drift more than 300 km (about 180 miles) from the release point [NOAA National Weather Service Radiosonde Observations].” Whether the different soundings alter the footprint and by how much will determine their usage in predicting the noise exposure at participant households.

Surface atmospherics will be monitored and archived throughout the day to stay abreast of turbulence conditions and to support post flight analysis.

Local resources shall be monitored as available and recorded in a running log. For example, if the study area includes a major metropolitan area, it is likely that a TV station has a meteorology department with a Doppler radar. While not essential to the test plan, such data could be used to ascertain the amount of turbulence in the atmosphere.

#29 IRB/OMB Approval

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
29	IRB/OMB Approval	3	0		3		3				2	0	0	9	0	9	0	0	0	18

- Condition:
    - IRB/OMB approval is required
- Departure:
    - IRB/OMB could impose significant constraints on our interaction with participants
- Affected Asset:
    - Execution of the experiment
- Consequence:
    - Increased expense and complexity
- Mitigation:

Early interaction with IRB/OMB. For the LBFD dose-response testing with the general public in the United States, both Institutional Review Board (IRB) oversight and Federal Office of Management and Budget (OMB) will be necessary. The majority of our proposed design is standard for noise survey research and research precedents will be identified. We will need to justify the rationale for including an estimation of the respondents' location in the survey data gathered.

A series of reviews with NASA and the PSU review boards were conducted during the development of the WSPR 2011 experimental design. A protocol was established between the Penn State IRB and the NASA IRB. The process proposed by the WSPRRR team will closely parallel that of the WSPR process for IRB reviews.

In preparation for non-acclimated community testing and gathering of subjective response data to low-amplitude sonic booms, we will also prepare a federal Office of Management and Budget (OMB) Application. The WSPRR team will prepare the OMB package. NASA has indicated that they will take the lead on submission of the application to OMB. The preparation of OMB and IRB applications shall be the responsibility of the WSPRRR team as described in Section 4.6. NASA has indicated that they will take the lead on submission to the OMB. Coordination between the PSU and NASA IRBs will be as dictated by NASA. OMB and IRB approvals shall be obtained prior to any recruitment or discussions with points of contact at regional sites or prominent communities. It is anticipated that approvals will be needed at least 3 months prior to test execution.

Any researcher conducting research involving human participants, who intends to be included on research publications, regardless of their direct contact with participating respondents, is required to complete IRB training. Training is valid for three years. To be included on the PSU IRB team, a PSU individual needs to activate the list of the team of researchers. The IRB information can be found at: http://www.research.psu.edu/orp/humans.

An individual can also complete training directly on the CITI program site, by setting up an account, indicating a research affiliation with PSU, and completing the training. https://www.citiprogram.org/

The Paperwork Reduction Act (PRA) of 1995 requires that OMB approve each collection of information by a Federal agency before it can be implemented. The information requested is intended to ensure that agencies employ effective survey and statistical methodologies that are appropriate for the type of information that is to be collected. The following information is required to be included in the OMB package:

21. Need for the Information Collection;
22. Use of this Information;
23. Detailed description set of questions, rationale;
24. Were the questions approved under prior approval number;
25. Efforts to Identify Duplication;
26. Burden on Small Business;
27. Consequences of Not Collecting the Information;
28. Special Circumstances;
29. Consultation and Public Comments;
30. Payments to Respondents;
31. Assurance of Confidentiality;
32. Sensitive Questions;
33. Burden hours to respondents;
34. Number of respondents, Number of responses per respondent;
35. Cost to Respondent (based on average hourly rate);
36. Cost to the Federal Government;
37. Publication of Results;
38. Procedures for the Collection of Information;
39. Information Analysis and Statistical correlations; andUse of Information.

#31 Introduction of Bias Versus an Informed Community

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
29	IRB/OMB Approval	3	0		3		3				2	0	0	9	0	9	0	0	0	18

- Condition:
  - A subtle approach to outreach has been proposed so as to minimize accusations of introducing bias into our subjective response
- Departure:

  - The general public may respond negatively if they are not informed
- Affected Asset:
  - Subjective response
- Consequence:
  - Negative general public reaction extending beyond the experiment participants
- Mitigation:

The subtle approach was chosen in an attempt to minimize full media coverage until the test was conducted and to not influence or bias the test communities' response.

The WSPRRR Outreach team will develop content for briefing community leaders, media releases and general Outreach material. We will conduct Outreach in conjunction with NASA representatives.

The WSPRRR communications approach needs to be fairly standardized across communities, while incorporating information that is specific to each geographic location. To do this, the team needs to be aware of community infrastructure, local demographics, community specific government structure and forums, and any cultural norms that are unique to that region. Because English is the recognized language for the United States, the test plan currently requires English speaking participants. However, our team can accommodate a multi-lingual approach if required by NASA, or dictated by the diversity within a selected geographic region.

The team will seek to identify and work with leaders in local government and community organizations, which may include, but is not limited to local city, borough and township officials, relevant community organizations and emergency responders. Initially we will need to determine if any permits are required, although that is not likely. The initial contact will be with government officials to inform them about the plans for the upcoming research based test. Emergency responders would be informed of the upcoming test as a precaution, to afford them the appropriate informational response in the event that the sonic booms generated during the experiment prompt concern from residents. We plan to be aware of the unique aspects of each community and will identify community specific outreach opportunities to create content focus for individual communities as needed.

General Outreach information will be distributed across the community after the research test is completed. We acknowledge that this information will be distributed beyond the test community, on a global scale. We will indicate in press releases at that time that future tests will be conducted to verify the results of our findings from the first community, in a location yet to be determined. In subsequent communities, we will still implement as subtle of a pre-test presence as possible, but will address any issues raised by pre-existing media coverage. We acknowledge that media coverage could bias our subsequent field tests. We are taking every precaution possible to ensure that our actions entering a community do not prompt media coverage, either positive or negative, that could raise a question of our biasing the respondents, and potentially cast doubt on the integrity of our research findings. We are cognizant that this test is being conducted for regulatory review, and as such, are taking additional precautions with our Outreach planning and the conduct of our Outreach efforts to ensure the validity of our research findings.

#7 Atmospheric Variability

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
7	Atmospheric variability	2	1	3		2			2		2	2	6	0	4	0	0	4	0	16

- Condition:
  - The specification for an LBFD experiment will place a carpet boom over an area approximately 36 miles wide and 50 miles long (1800 sq miles).
- Departure:
  - Environment may vary spatially and temporally from discrete measurements prior to flight
- Affected Asset:
  - Boom analysis
- Consequence:
  - Variations in the atmosphere could result in changes to the propagation of the boom
- Mitigation:

Environmental monitoring, see risk #5 Diurnal Effect. Given that we recognize that environmental monitoring/modelling will be required we consider the probability of significant variation of the boom intensity and footprint from our predictions to be low (2). As part of our site selection we intend to consider the climatology of each site through our Site Selection process (1). Environmental monitoring utilized to support boom predictions will be part of our Flight Operations process (3). Some minor variation from predicted levels can be expected and will be of low consequence to Dose Response (2) and will be a factor for consideration in Boom Analysis (2).

#12 Construction Variability

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
12	Construction Variability	2	2	0		2			4		2	4	0	0	4	0	0	8	0	16

- Condition:
  - The LBFD Test Deployments will be conducted over six regions across the country
- Departure:
  - Construction will vary significantly across these regions and include multiple types of structures which have not all be assessed for their vulnerability to low boom effects.
- Affected Asset:
  - Site selection

- Consequence:
  - o Variation in construction types that have not been assess for vulnerability to low boom effects could result in some structures being more prone to these effects including the possibility of damage.
- Mitigation:

In order to ensure the total participant population and geographic areas selected are representative of the entire United States, sites were initially chosen from one of five climate zones (Figure F-14), as defined by Building America [Baechler *et al.,* 2013].

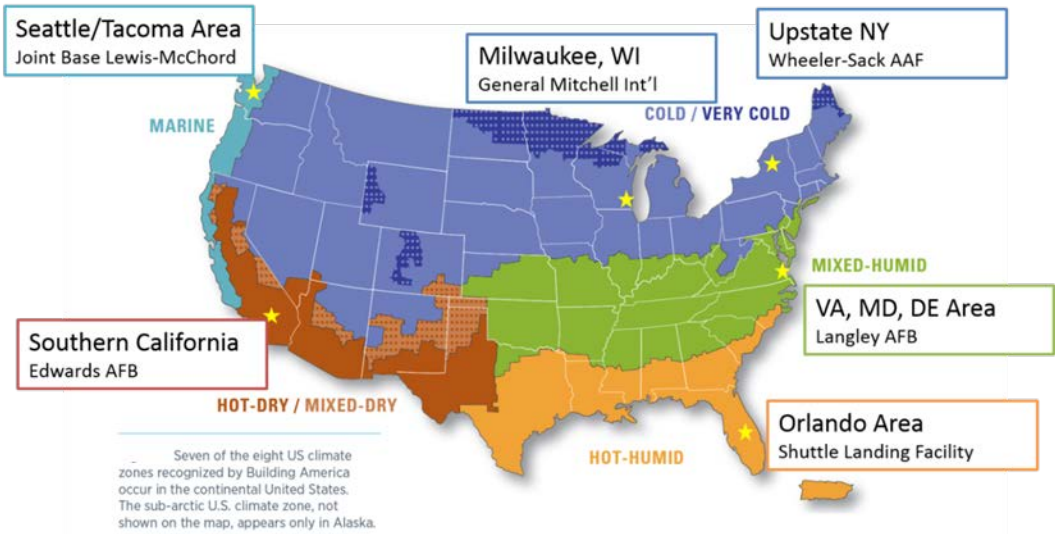


Figure F-14 US Climate Zones and Preliminary LBFD Test Sites

By selecting areas in each of these climate zones, we are able to represent a wide range of potential meteorological and atmospheric conditions, as well as community layouts and designs, building materials, and population densities.

We investigated building response to Sonic Booms and noted damage is not likely (see #14 Boom Level Enhancement Through Structural Configuration). High rise buildings and particularly V shaped buildings (where the shock wave enters the open part of the V) can be susceptible to enhancement of the sonic boom and possibly some minor damage. Given that the LBFD is anticipated to deliver a .3 psf boom the possibility of damage is considered minimal, however the low boom delivered from an F-18 LBDM may result in higher Δp. Figure F-15 presents typical high rise beach front construction that can be found in coastal communities such as Panama City Florida.

Figure F-15 **High Rise construction along the Panama City Coastline**

A key mitigation strategy for this will be through the identification of these structures as part of our Phase 2 Site Selection Process as detailed in section 11.4.1. Such structures may require additional outreach efforts, pre-test surveys, and noise monitoring during the F-18 dive flight test. One of the items to be considered in Phase 2 is the incoming sonic boom propagation ray angles relative to the high rise buildings. The F18 dive maneuver results in long propagation distances at low angles relative to the ground whereas the LBFD overflights will have larger incoming ray path angles.

#3 Supersonic Turn Focus

	Risk Title	***Prob***	**#1 Site Logistics Consideration & Selection**	**#2 LBFD Parameters, Focus Booms & Flight Ops**	**#3 Communications and Outreach**	**#4 Survey and Dose Response**	**#5 Survey Implementation and Recruitment**	**#6 Noise Measurements**	**#7 Boom Analysis**	**#8 Data Analysis**	**Average**	**#1 Site Logistics Consideration & Selection**	**#2 LBFD Parameters, Focus Booms & Flight Ops**	**#3 Communications and Outreach**	**#4 Survey and Dose Response**	**#5 Survey Implementation and Recruitment**	**#6 Noise Measurements**	**#7 Boom Analysis**	**#8 Data Analysis**	***Total Impact Across Design***
3	Supersonic Turn focus booms	1	4	4		4					4	4	4	0	4	0	0	0	0	12

- Condition:
    - An a/c making a supersonic turn may create a focused boom that reaches the ground.
- Departure:
    - Possibility of the focused booms impacting the Participant community
- Affected Asset:
    - Site selection
    - Flight Operations
    - Survey and Dose Response
- Consequence:
    - Focused booms encroaching the participant community could result in a negative response
- Mitigation:

Once an appropriate airport site is found using the method described, a conceptual flight path must be created, illustrating the general direction of flight and location of turns if necessary. Once the exposure area is set, the flight path is extended to show the path from the airport runway to the start of the on-design sonic boom carpet portions of the community noise exposure, including any turns that may be necessary to achieve the correct headings. These turns could potentially result in focus booms if the aircraft is travelling at supersonic speed, so it is necessary to design the total flight path such that focus booms are mitigated or placed over areas with very little or no population.

Turn focus may be avoided by reducing to subsonic speeds following a sonic boom community pass and exposure while positioning the aircraft for any subsequent flight passes. Using aircraft performance information and the PCBoom software suite, approximate pressure contours have been modeled and plotted under the proposed flight paths to determine if and where focus booms might exist. One of the important criteria in site selection is proximity to large bodies of water and/or sparsely populated areas, precisely for the purpose of placing focus booms away from large communities.

Focus booms may or may not occur due to turns depending on the parameters of each maneuver, which can be modeled in PCBoom to determine if a focus exists. If the flight path requires turn over a populated community, the aircraft must be decelerated below supersonic to avoid any boom altogether. This will necessitate another acceleration from subsonic to supersonic speed with its unavoidable transition focus boom region followed by the climb to cruise condition. Figure F-16 illustrates to scale a climb transition focus to climb to cruise sonic boom footprint and overpressure levels for the Hot-Humid Region for a westbound flight. The subsonic to supersonic transition focus is the higher amplitude (psf) contours on the eastern portion of the footprint. And nominal cruise conditions are achieved at the eastern seaboard. During detailed operational design once the LBFD has been designed, this analysis will need to be revisited using the LBFD aircraft flight performance capabilities.

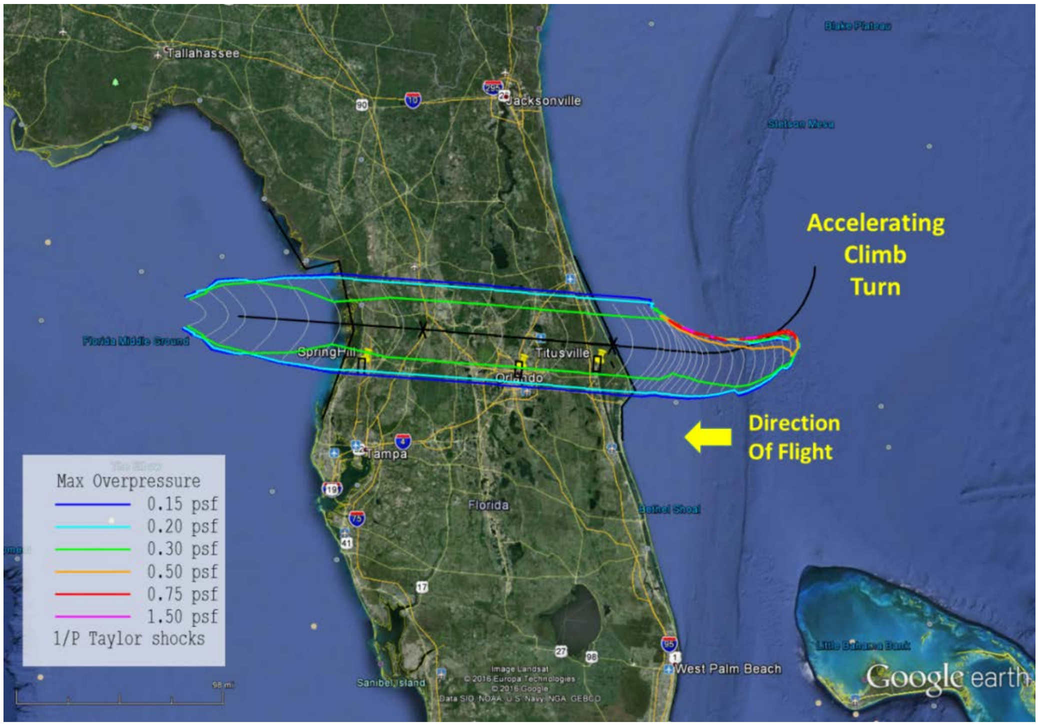


Figure F-16 Climb Acceleration Flight track, Focus & Carpet Sonic Boom Footprint, Hot-Humid Region

#9 Unattended Remote Controlled Noise Monitors

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
9	Unattended/Remote controlled noise monitors	3	0					4			2	0	0	0	0	0	12	0	0	12

- Condition:
    - Participant coommunities will be selected from carpet boom region which can be 2000 sq miles..
- Departure:
    - Clusters of monitors may be widely separated
- Affected Asset:
    - Noise Measurements
- Consequence:
- Controlling and access to measurements will require a wide area network which cannot be supported through line of sight wifi
- Mitigation:

An advantage of the WSPR experiment at EAFB was that the subjective respondents were densely located over an area of approximately 1 mi^2. This allowed for the 13 Field Kits to be networked to a host station by using of bi-directional, long range 2.4GHz wireless G Wi-Fi through the field kit TCP/IP network connections on the cRIO 9023 chassis. Limitations of this sort of network is that it is generally restricted to line of site operations for effective, continuous operation and wireless repeaters are required for long range operation, increasing the number of potential failure points between a field kit and a host station. Equipment tests prior to the WSPR experiment showed that individual repeater units needed to be configured with multiple routers and antenna in an Access Point/Client configuration to improve network reliability and performance. Additionally, it was determined that the communication chain should not perform more than three “hops” to ensure network integrity. A total of five repeaters were used in the densely spaced community at EAFB (Figure F-17).

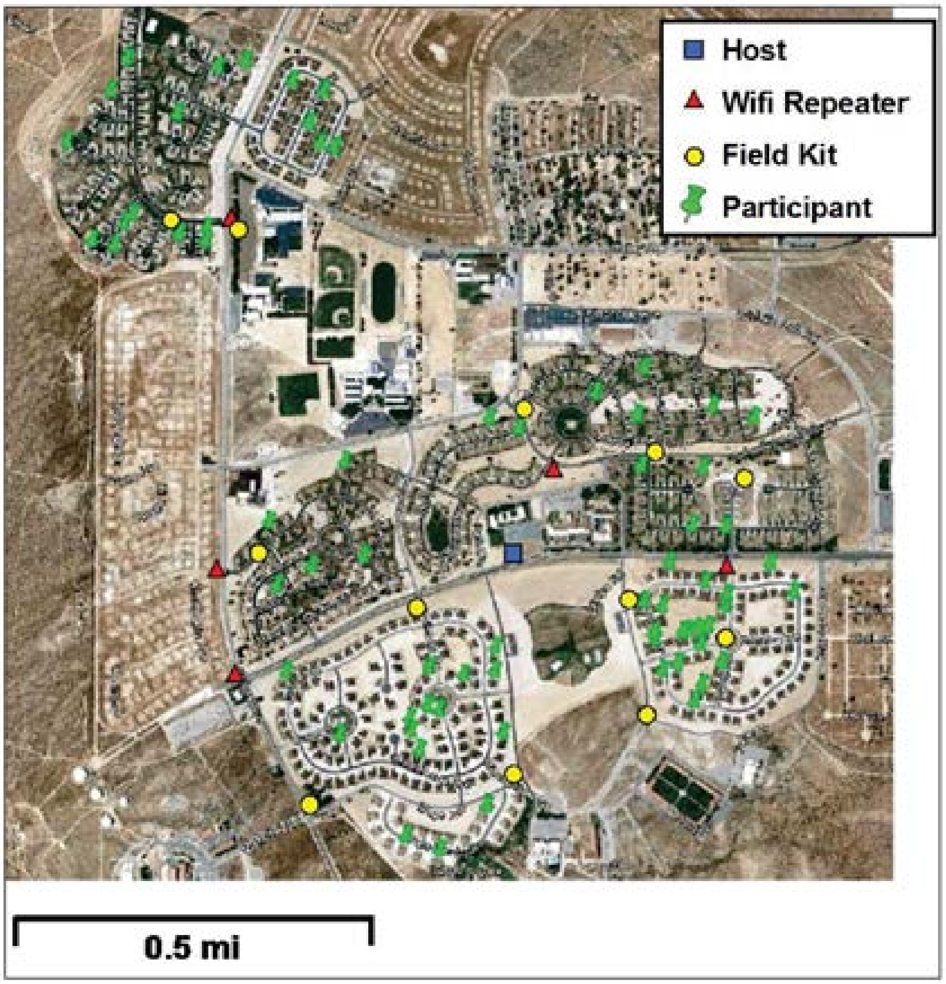


Figure F-17 Community Layout for 2011 WSPR Test

Due to the anticipated expansion of the community footprint for the QueSST experiment (as described in section 6.4 of the Conceptual Test Plan), along with the understanding that respondents may be clustered within different areas inside of these larger communities, it is not likely that the networking strategy employed in WSPR will be sustainable. Thanks to the expansion and improvements of cellular networks over the past half of a decade, the best option for networking remote noise monitors lies with cellular connectivity.

Since the SBUDAS nodes already feature TCP/IP network connectivity and are programmed with set static IP addresses, the modification effort would be consist of obtaining and configuring cellular modems for individual nodes, and establishing a base station and VPN server for network connectivity (Figure F-18).

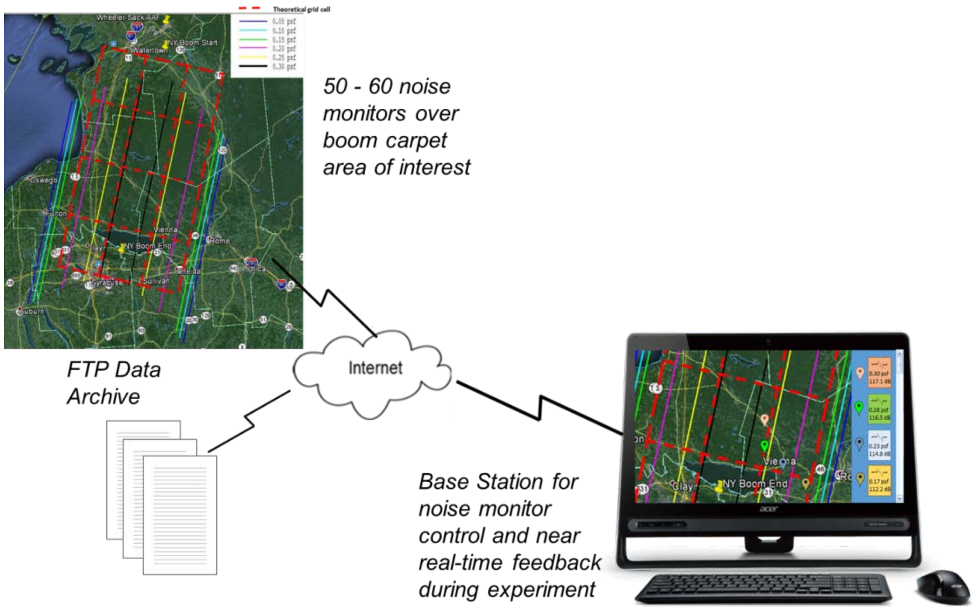


Figure F-18 SBUDAS Network Connectivity

Cellular modems or routers, such as the Digi Connect product line, can be purchased with the capability of supporting 10/100/1000 Ethernet connections and operating at 2G (Edge), 3G, or 4G (LTE) speeds on CDMA (Verizion/Sprint) or GSM (AT&T/T-Mobile) networks. Modems offer basic routing and security, with enterprise versions providing advanced routing and security/VPN. These systems are designed to run in remote, low power applications and can be powered using the system 12V batteries.

A modem such as the Digi TransPort WR11 in its North American 4G LTE GSM configuration would be capable of support 4G data on 700/850/1700/1900 MHz bands with 2G and 3G fallback on 850/1900 MHz (AT&T provider) bands with maximum transfer rates on supporting networks of 50 Mbps upload and 100 Mbps download. These modems cost about $370 each (as of mid-2015) and feature plastic cases since they are designed for permanent installations for equipment such as ATMs or Kiosks.

An alternative option is the Digi WR21-L52B series modems – these have cellular chipsets that allow for them to be used with any carrier using a SIM card at 4G/LTE speeds since 4G uses GSM bands and are therefore available from CDMA providers. These units provide 2 Ethernet connections and a rugged construction with a metal case. These modems cost about $530 each (as of mid-2015) without SIM cards or data plans.

All noise monitors would be connected to cell modems and could be assigned a static IP based on the unit MAC Address.

A base station computer running NI Labview is required to configure and set triggers for the remote noise monitors. Any computer running Windows 7 or Windows 8 has the ability to natively operate as a VPN server without any sophisticated or expensive software. If a computer were configured and connected to act as a server, it could also operate as a remote webhost for noise monitor triggering, monitoring, and data retrieval. Data collected by remote noise monitors would be able to be securely transmitted over the cellular VPN to a base station via any File Transfer Protocol (FTP) software for remote data collection purposes. Remotely retrieved data would continue to be stored locally on the noise monitors for redundancy.

The base station system could be tied into the network by using a cellular modem, like those used for the SBUDAS, however the amount of bandwidth it would consume would scale by the number of SBUDAS receiving triggers and health queries, and responding with data files. It would be preferable that a Base Station be setup on a network capable of supporting continuous, high bandwidth use.

Thanks to the expanding consumer cellular market, a variety of mobile broadband data plans are available for supporting tablets and SIM card enabled PCs. These can be purchased under different terms of use, bandwidth, and for different durations depending on operational needs.

- If long term data connectivity is required, contract based machine to machine (M2M) data plans from major carriers such as Verizon or AT&T may be preferable for stability. In 2014, 3G data plans with 5GB bandwidth caps were available for a contract rate at $60/month.
- Reviewing mobile broadband data plan for tablets (mid-2015), medium term monthly contracts, or prepaid plans with 30-day expiry periods, can be purchased for less than $10/GB of data at 4G speeds – with prices falling for higher bandwidth requirements.
- Short term (1 to 7 day) prepaid plans can be purchased at costs between $10-20/GB at 4G speeds.

Many of these plans require an upfront cost of $10-15 for carrier SIM cards. Day to week long plans are unlikely cost-effective options when considering the man-hours that will be required to activate all the network nodes and configure the modems.

#11 Interior Noise

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
11	Interior Noise	2	0			0		3	3		2	0	0	0	0	0	6	6	0	12

- Condition:
  - Propagation of low impact sonic booms through dwelling envelopes is being investigated, but not yet fully documented over varied construction types.
- Departure:
  - Noise transmission through structures, from single family dwellings to skyscrapers, is inferred from construction types. Windows and roofs (common source of noise “leaks”) are often varied by homeowners
- Affected Asset:
  - Noise Measurements
- Consequence:
  - Controlling and access to measurements will require a wide area network which cannot be

supported through line of sight wifi

- Mitigation:

It is anticipated that the regulatory community is seeking to establish a single metric and regulatory threshold level rather than separate metrics and thresholds for indoors and outdoors. Our team is taking the approach that outdoor boom measurements will be sufficient to correlate with response. The response includes both the human perception plus the building element, with the input stimulus described by the outdoor sonic boom metrics. Given the uncertainty created by the wide variety of building types, the participant's location within a building, the impractical nature of such precise dose identification, and leveraging the very close correlation between indoor and outdoor metrics demonstrated in the WSPR 2011 project and others[‡‡] our design employs only outdoor measurement of noise at a Participant's location for dose-response correlation for the LBFD Test.

We propose including questions in baseline survey on house construction type, however, metric calculations will be based on external noise measurement. We plan to identify a typical building structures for that geographic region ahead of the experiment and determine if further assessment is warranted. If feasible we propose to use accelerometers in a typical building type to assess the potential for primary and secondary vibration of walls or windows.

#16 Anecdotal Influence

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	***Total Impact Across Design***
16	Anecdotal Influence	2			3	0	3				2	0	0	6	0	6	0	0	0	12

- Condition:
  - Over the course of the experiment it is anticipated that participants will be engaged and possibly influenced by non-participants and that additionally non-participants may express their opinions through social media and other means.
- Departure:
  - Small number of non-participants could loudly and negatively respond outside our measured Participants

[‡‡] In the EAFB [Kryter, 1967] and Exercise Westminster tests [Webb & Warren, 1965; Johnson & Robinson, 1967] indoor & outdoor dose-response comparisons were made. For the EAFB tests only outdoor measurements of the boom were used when assessing the people's indoor responses [NSBEO, 1967]. Schomer, Sias and Maglieri [1997] found that "C- weighting is a useful outdoor measure for assessing the indoor community response to high energy impulsive sounds". Setting aside for now his "C" weighting, the point being made is that indoor responses should be correlated with an outdoor metric. Also Leatherwood *et al.,* [2002] point out that PLdB is "clearly a good metric for outdoor listening of booms and there is some indication that it worked quite well indoors."

- Affected Asset:
  - Noise Measurements
- Consequence:
  - Unquantifiable social response could override our measured social response
- Mitigation:

Researchers currently at Penn State, Volpe, Gulfstream and Wyle have teamed for the past several years on various low boom research efforts as part of the Partnership for Air Transportation Noise and Emissions Reduction (PARTNER), an FAA/NASA/TC sponsored Center of Excellence (COE). The PARTNER Sonic boom team conducted research until 2013 under when that COE concluded. The PARTNER team of researchers expanded their team and subsequently formed the Aviation Sustainability Center (ASCENT), a new FAA sponsored Center of Excellence. The low boom research is being continued by this team of researchers through the ASCENT Supersonics Team. As part of the ASCENT sponsored Supersonics effort, researchers are investigating optimal approaches to monitor boom impact. One approach under investigation is the use of social media monitoring implemented in a form of pro-active Outreach. On-line observation of public domain comments will allow our team to quickly address concerns with a proactive press release, taking prompt action to contain any potential viral negative media.

Social media monitoring tools have been identified that allow monitoring to be conducted in a defined geographic area. The team would need to identify key words to monitor on select social media sites. The geographic area could be defined to include all communities under the flight path. This allows us to monitor responses on social media in areas where we may not have noise monitors or formal respondents. The comments on social media could provide insight into a reaction to a boom impact that we didn't anticipate. The monitoring of social media is the equivalent of a soft sensor implemented to alert us to extreme events (an unexpectedly loud boom impact) and to observe reactions within the community. The monitoring would be conducted over a one month period for each geographic site. Monitoring would begin one week before the test, continue throughout the field test, and for one week after the test. Monitoring the week before the test allows us to determine if there are any noise related issues within the community at the time of the test or if there is any pre-test on line discussion of our upcoming field test. Monitoring the area for a week following the test allows us to observe community comments. We can use this as feedback to better inform future new releases or outreach content. During the test, we will be using social media monitoring (SMM) to observe if there is any indication of a viral negative community response to the flight tests. We will have press releases and information available for immediate distribution if needed as the research progresses. In the event that concerns are observed within the community or through SMM, we can distribute press releases immediately that address those concerns.

Social media monitoring (SMM) will be utilized to seek and identify any indications of viral negative community response to the flight tests. Viral social media could be posted as a result of loud boom like noises outside the test area, unintended focus signatures impacting areas due to changing atmospheric conditions or someone responding from a water-borne location (i.e. boat) under the focal region. In the event that concerns are observed within the community or through SMM, the test plan calls for immediate distribution of press releases that address those specific concerns.

#6 Turbulence Detection

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
6	Turbulence detection	2	1					2	2		2	2	0	0	0	0	4	4	0	10

- Condition:
  - Atmospheric turbulence will affect the propagation of low boom effects. Detection of atmospheric turbulence is based on significant variations in acoustic measurements between closely located noise monitors
- Departure:
  - Atmospheric turbulence will affect the noise dose experienced by participants.
- Affected Asset:
  - Site selection
  - Noise Measurements
  - Boom Analysis
- Consequence:
  - Unquantifiable social response could override our measured social response
- Mitigation:

Include as part of the Site Selection Process a review of historical climatological data with respect to atmospheric condition that are known to contribute to turbulence. Atmospheric turbulence can significantly affect the noise perceived by subjective respondents. We will monitor environmental measurements and forecasts to predict when and where atmospheric turbulence may occur relative to the locations of our respondents. Past experiences has shown that noise monitors will be arranged in an L configuration separated by 100 feet will indicate the presence of turbulence via the peaking and rounding of the boom signatures. Such an arrangement will be deployed in the vicinity of where respondents are anticipated to be located as shown in Figure F-19.

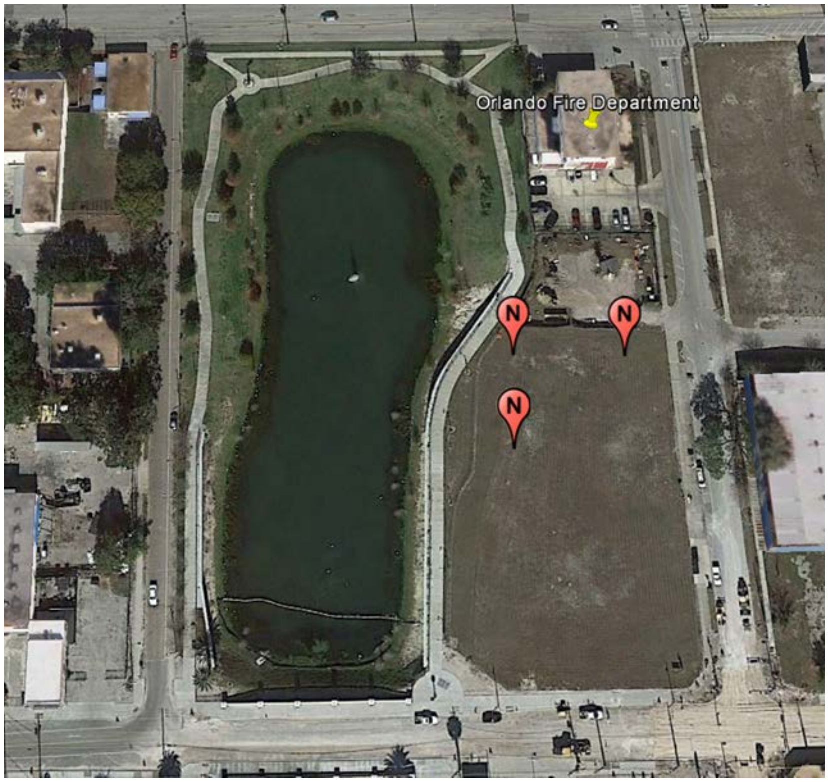


Figure F-19 Noise Monitor Placement for Detection of Turbulence

The purpose of these monitors is to determine whether or not the respondents were subjected to enhanced boom effects due to turbulence. These noise monitors can serve multiple purposes in that they can detect turbulence and additionally collect objective measurements for correlation with subjective responses. The total number of noise monitors configured in this manner will depend upon the distribution of our subjective respondents and the environmental variability across the carpet region. At a minimum, each community center within the carpet region will have at least three monitors in this configuration.

We recognize that NASA research and investment in the SonicBAT program is quickly expanding our understanding, modeling capabilities and validation datasets of turbulence effects on sonic booms. Additionally SonicBAT will add to the knowledge base, an understanding of the upper air conditions which foster the development of turbulence spiking and rounding on measured ground boom signatures. Members of our team are engaged in the SonicBAT studies and will develop and validate numeric models that are capable of computing propagation of arbitrary boom signatures through a variety of turbulent structures. Flight tests will be conducted at three locations in the US in a variety of climates to obtain validation data. Results from the numeric model, finite impulse response (FIR) filters, will be used to expand the existing suite of FIR filters in PCBoom and provide a range of atmospheric turbulence and climate parameters for which stochastic perturbations in the sonic boom metrics can be determined. This future capability can be utilized in conjunction with the LBFD measurements to refine the interpolation process for obtaining metric values at participant locations.

#19 Night Flights/Sleep Disturbance

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
19	Night Flights - Sleep Disturbance	1	0		3	3				3	2	0	0	3	3	0	0	0	3	9

- Condition:
  - LBFD is designed to support night flights.
- Departure:
  - If flown at night some participants may be awakened
- Affected Asset:
  - Communications and outreach
  - Survey and dose response
  - Boom Analysis
- Consequence:
  - Adverse affect upon public perception
- Mitigation:

Sleep disturbance is not included in the scope of this test plan and will require a separate substantial effort. Awakenings by participants who go to bed before the last flight or who might sleep during the days (i.e. night-shift workers) will not be included in this test plan. It is possible that working nights could be potential disqualification grounds during recruitment; however this has not yet been finalized. The design of the flight times (in progress) will also take this into consideration. For the LBFD test, there should be no sonic booms after 9 pm local time. If night time flights are added, we can add an End of Night Survey.

It should be noted that with the return of the Space Shuttle Orbiter to EAFB that complaints from surrounding communities were not common during daylight landings, however a 4AM boom, which was advertised in the press, did result in complaints. Additionally during the U.S. SST effort back in the late 1960's & 70's when the 1964 OKC overflights were being made there was a criticism from Sociologist Kingsley Davis of the Univ. of Calif. at Berkeley who said that "the tests had omitted the most important question of all, the public's response to night booms".

#10 Noise Monitor Security

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
10	Noise Monitor Security	2	1					3			2	2	0	0	0	0	6	0	0	8

- Condition:
  - Noise monitors will be unattended and distributed across communities

- Departure:
  - Noise monitors could be subject to theft and vandalism
- Affected Asset:
  - Site Selection
  - Noise Measurements
- Consequence:
  - Loss of noise monitors and their measurements
- Mitigation:

We have proposed a mixed fidelity approach for noise measurements, employing expensive high fidelity SBUDAS field kits along with low cost noise monitors. Through our Site Selection process we will identify public works facilities that could offer security for installation of the expensive SBUDAS field kits. Low cost noise monitors would be constructed in a low profile weatherproof enclosure which could be discretely secured to rigid structures or in discrete locations less prone to theft or vandalism.

#15 Second Effect Damage or Injury

	Risk Title	*Prob*	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	Average	#1 Site Logistics Consideration & Selection	#2 LBFD Parameters, Focus Booms & Flight Ops	#3 Communications and Outreach	#4 Survey and Dose Response	#5 Survey Implementation and Recruitment	#6 Noise Measurements	#7 Boom Analysis	#8 Data Analysis	*Total Impact Across Design*
15	Second effect damage/injury	1	0		3	3					2	0	0	3	3	0	0	0	0	6

- Condition:
  - Low booms have a very low but not non-existent probability of causing damage to structures
- Departure:
  - Damage to structures could result in in second effect damage or injury, i.e. a broken window could result in a person being cut.
- Affected Asset:
  - Communications and outreach
  - Survey and Dose Response
- Consequence:
  - Any damage or injury can influence public perception of the test deployment.
- Mitigation:

As discussed in #28 Low Frequency Building Excitation, the possibility of damage from a low boom is considered extremely remote. NASA has acknowledged that ultimately the liability for a safe deployment resides with the government however pro-active community engagement and modelling the boom across the carpet region should sufficient mitigate this risk to an acceptable level.

B. Site Selection Grids and Community Demographics

The following pages provide Appendix B. This appendix file is provided separately from the main body of the report.

B. Site Selection Grids and Community Demographics

Graphics in this appendix reflect the site selection process described in Section 4.2. They represent a meteorological analysis described in Appendix C and include upper air data from 2006 to 2016 for August, September, October and November months. Table B-1 itemizes the sonic boom footprint area for the 60% and 80% overpressure criterion as utilized in the Z-score site selection process. The 2010 US census data was utilized and representative prominent communities were selected in three of the four recruitment zones (identified by the white quadrilaterals). During the test design phase only three of the four quadrants were utilized due to limitations in the number of acoustic instrumentation nodes available for objective data collection during QSF18. The demographic plots indicated the selected prominent communities (circles) and the overall US demographics (blue diamonds).

The even numbered figures contain an illustration of the population density for the region of interest based on the 2020 census data. The table on the right itemizes the three identified prominent communities for three of the recruitment quads (top and right quads). The table itemizes the total population, the percentage of the population per prominent community, the number of desired participant recruits per community and the total number of target addresses to which recruitment letters need to be sent in order to achieve the desired number of participants.

Table B-1 Sonic boom footprint area for the 60% and 80% overpressure criterion

2,000 ft cells

Site	Area (60% overpressure criterion)	Area (80% overpressure criterion)
FL: Titusville	176.1 nmi^2	143.2 nmi^2
Tx: Galveston	178.3 nmi^2	151.4 nmi^2
MA: Cape Cod	186.5 nmi^2	152.7 nmi^2
AL: Gulf Shores / Orange Beach	212.4 nmi^2	176.0 nmi^2
FL: Panama City, Laguna Beach	235.6 nmi^2	182.4 nmi^2

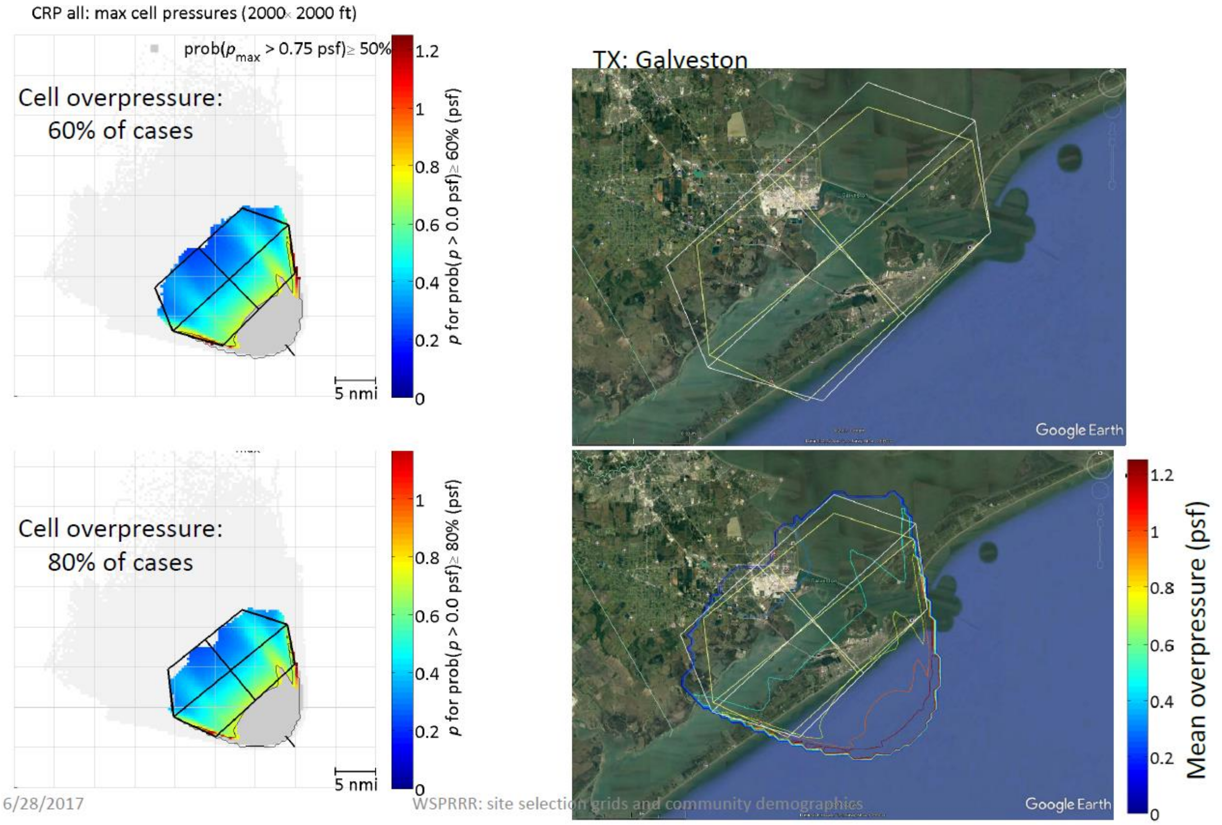
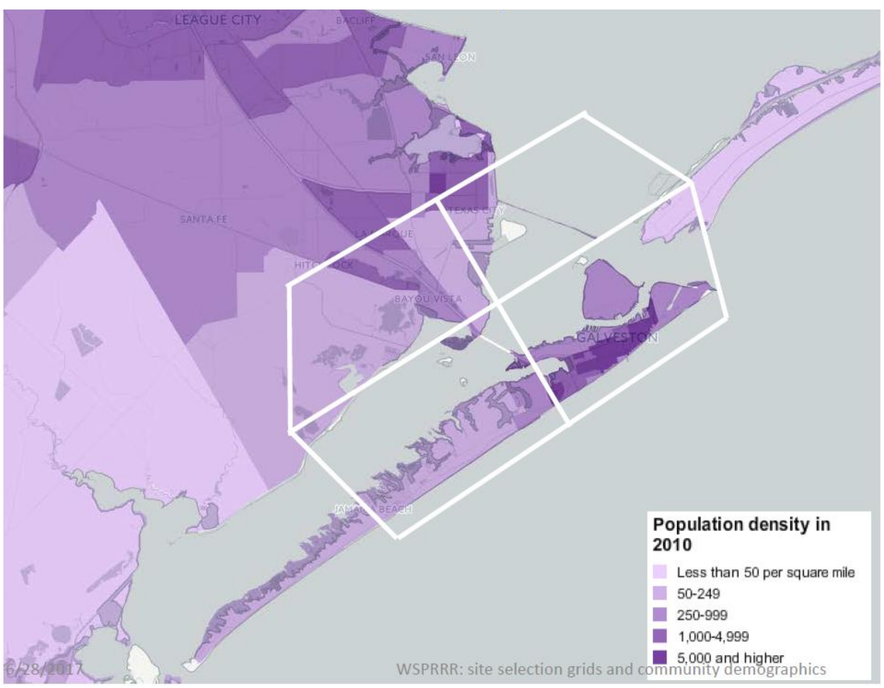


Figure B-1 Galveston TX meteorological analysis probability of low amplitude sonic boom delivery



Hitchcock	Texas City
Galveston	
Total Population	
6,961	45,099
47,743	
Percentage	
6.97%	45.19%
47.84%	
Recruits per Community	
35	226
239	
Targets Required	
157	1,017
1,076	

Figure B-2 Galveston TX community recruitment and population density

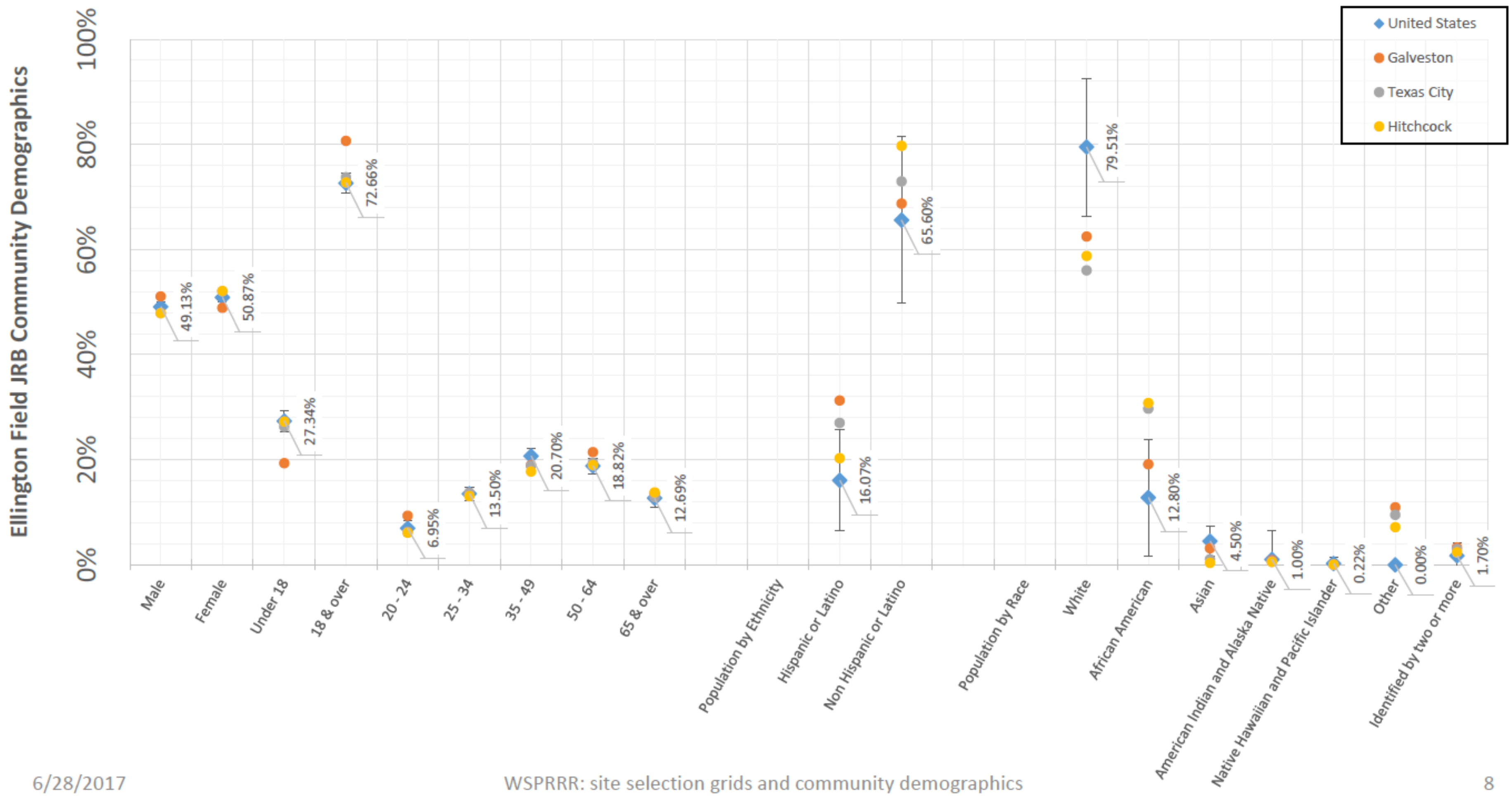


Figure B-3 Galveston TX community demographics dashboard

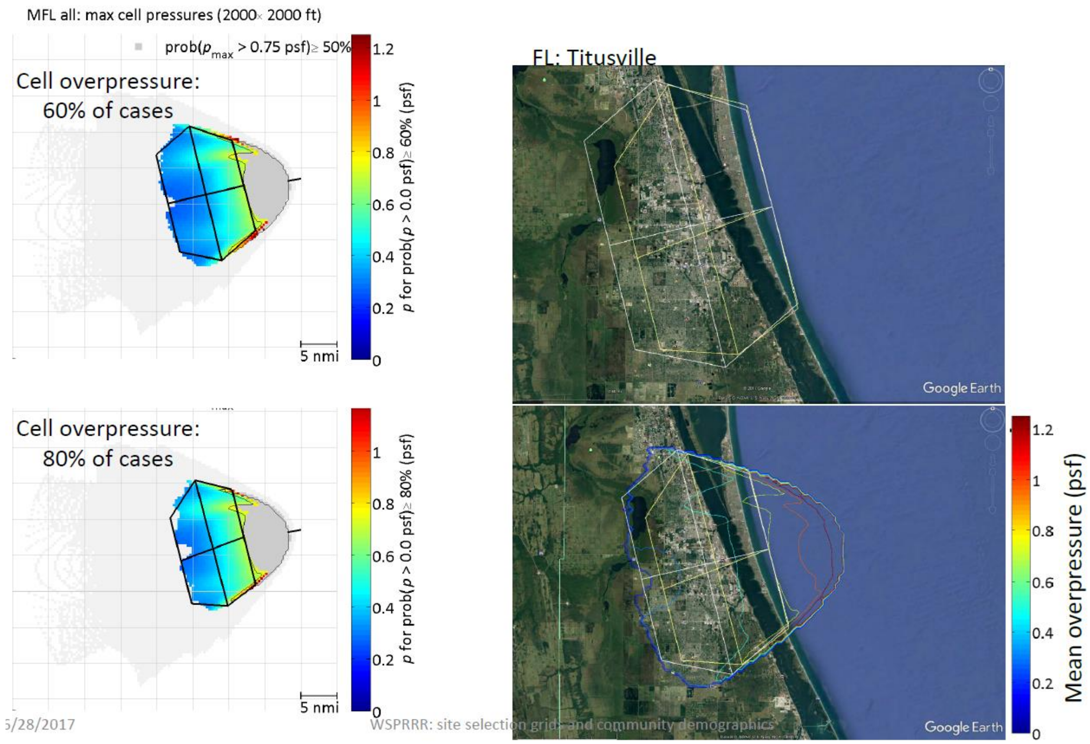
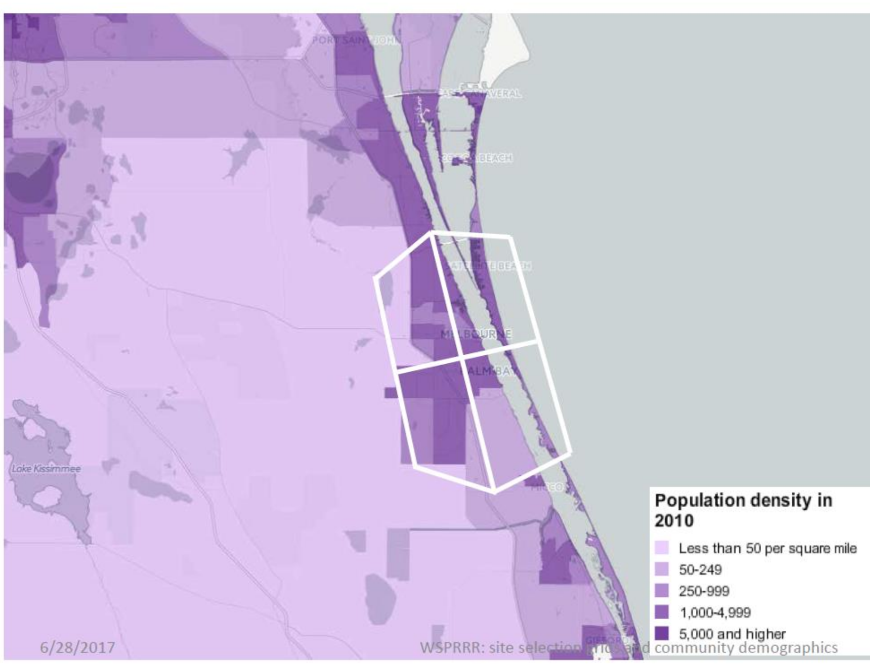


Figure B-4 Melbourne, FL meteorological analysis probability of low amplitude sonic boom delivery



West Melbourne	Melbourne
Palm Bay	Satellite Beach
Total Population	
18,355	76,068
103,190	10,109
Percentage	
8.84%	36.62%
49.68%	4.87%
Recruits per Community	
44	183
248	24
Targets Required	
199	824
1,118	109

Figure B-5 Melbourne, FL community recruitment and population density

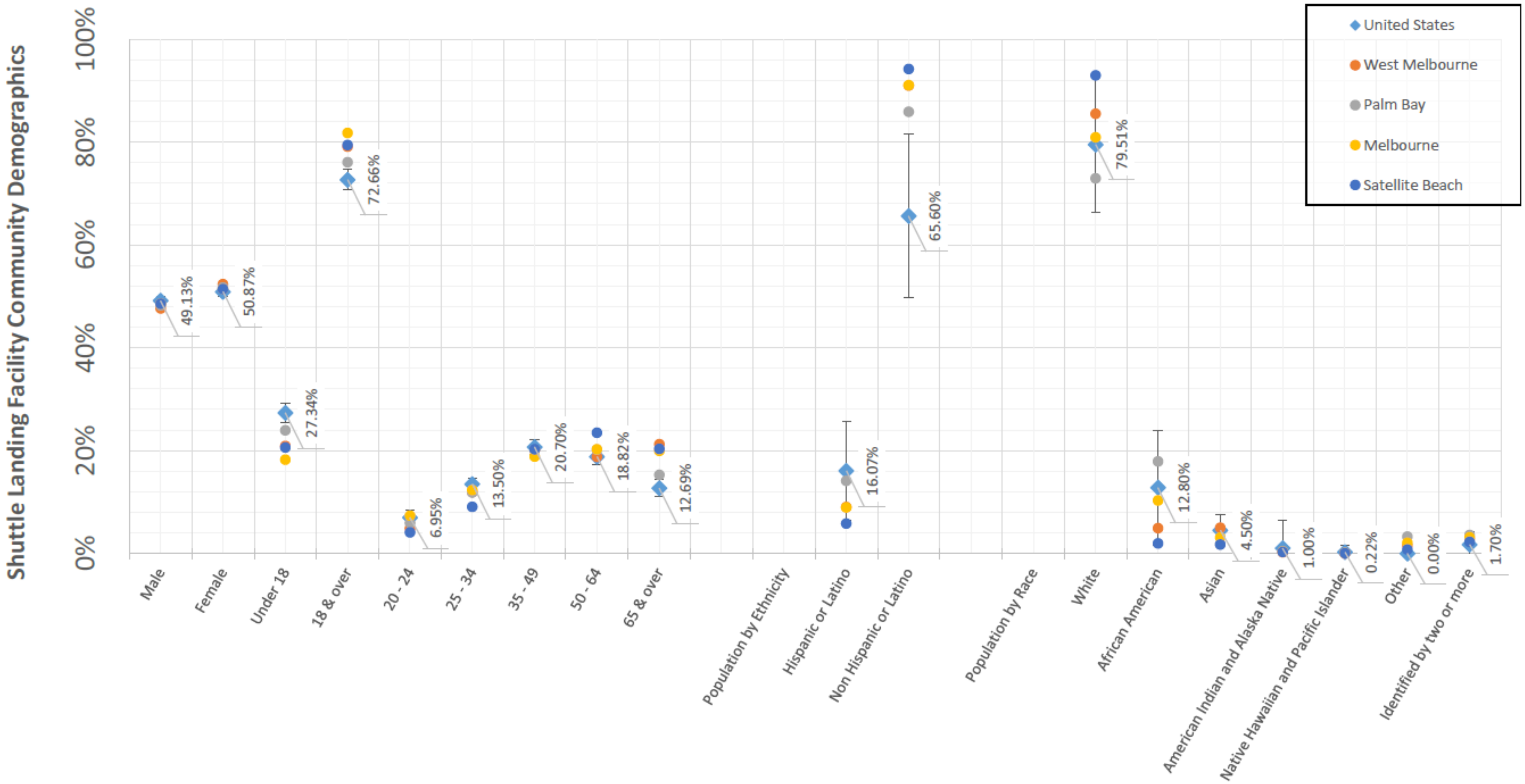


Figure B-6 Melbourne, FL community demographics dashboard

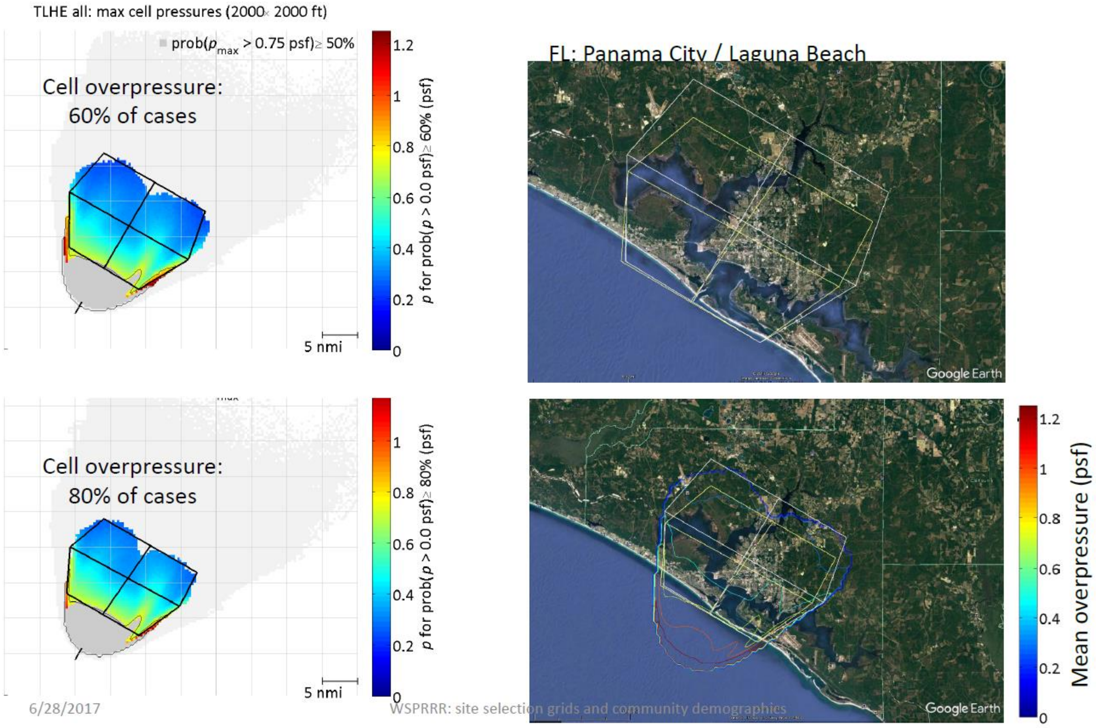
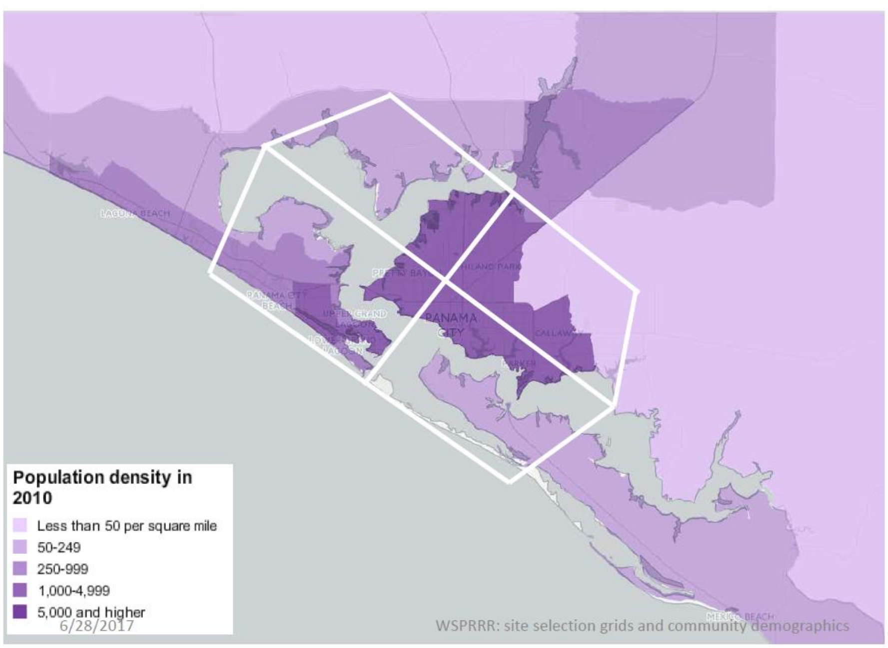


Figure B-7 Panama City, FL meteorological analysis probability of low amplitude sonic boom delivery



	Panama City Beach	Lynn Haven	Panama City
Total Population	12,018	18,493	36,484
Percentage	17.94%	27.60%	54.46%
Recruits per Community	90	138	272
Targets Required	404	621	1,225

Figure B-8 Panama City, FL community recruitment and population density

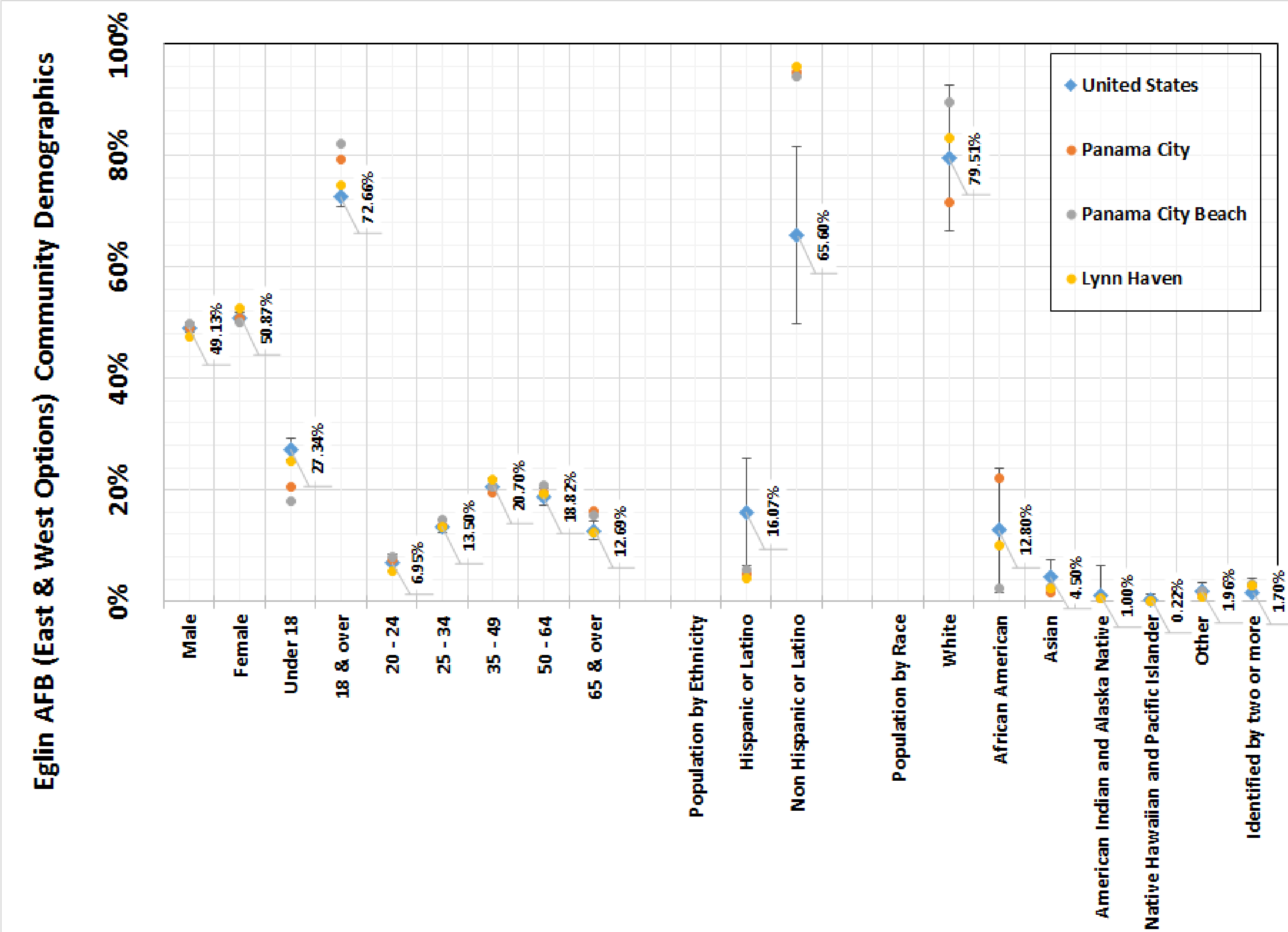


Figure B-9 Panama City, FL community demographics dashboard

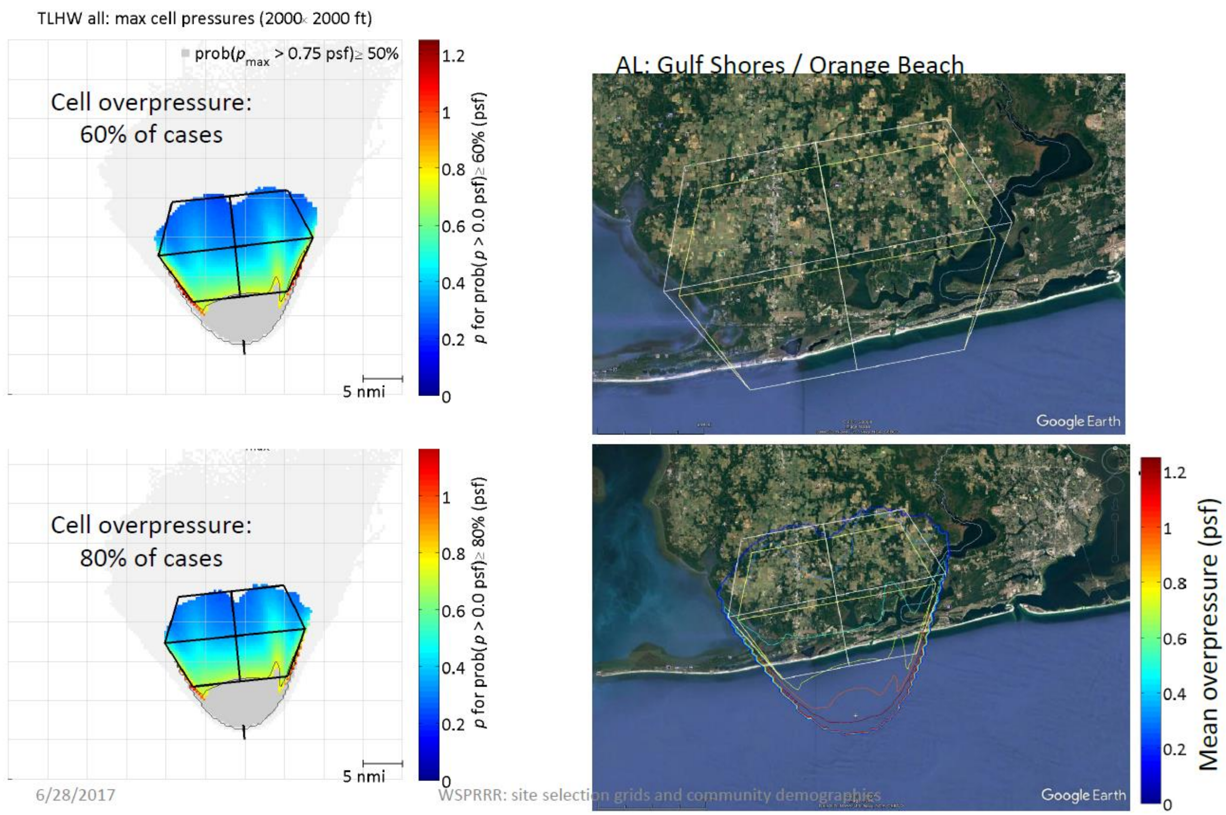
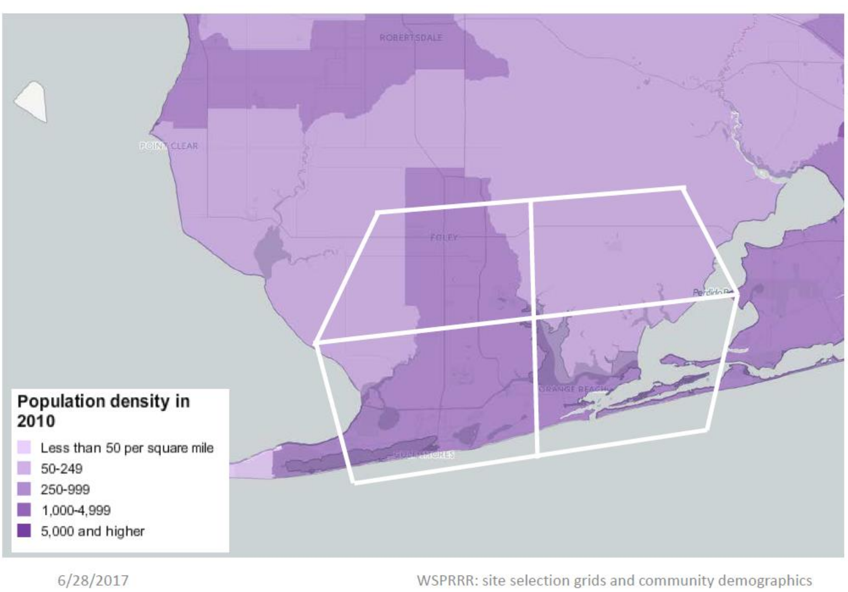


Figure B-10 Gulf Shores/Orange Beach, AL meteorological analysis probability of low amplitude sonic boom delivery



Foley	Elberta
Gulf Shores	Orange Beach
Total Population	
14,618	1,498
9,741	5,441
Percentage	
46.71%	4.79%
31.12%	17.38%
Recruits per Community	
234	24
156	87
Targets Required	
1,051	108
700	391

Figure B-11 Gulf Shores/Orange Beach, AL community recruitment and population density

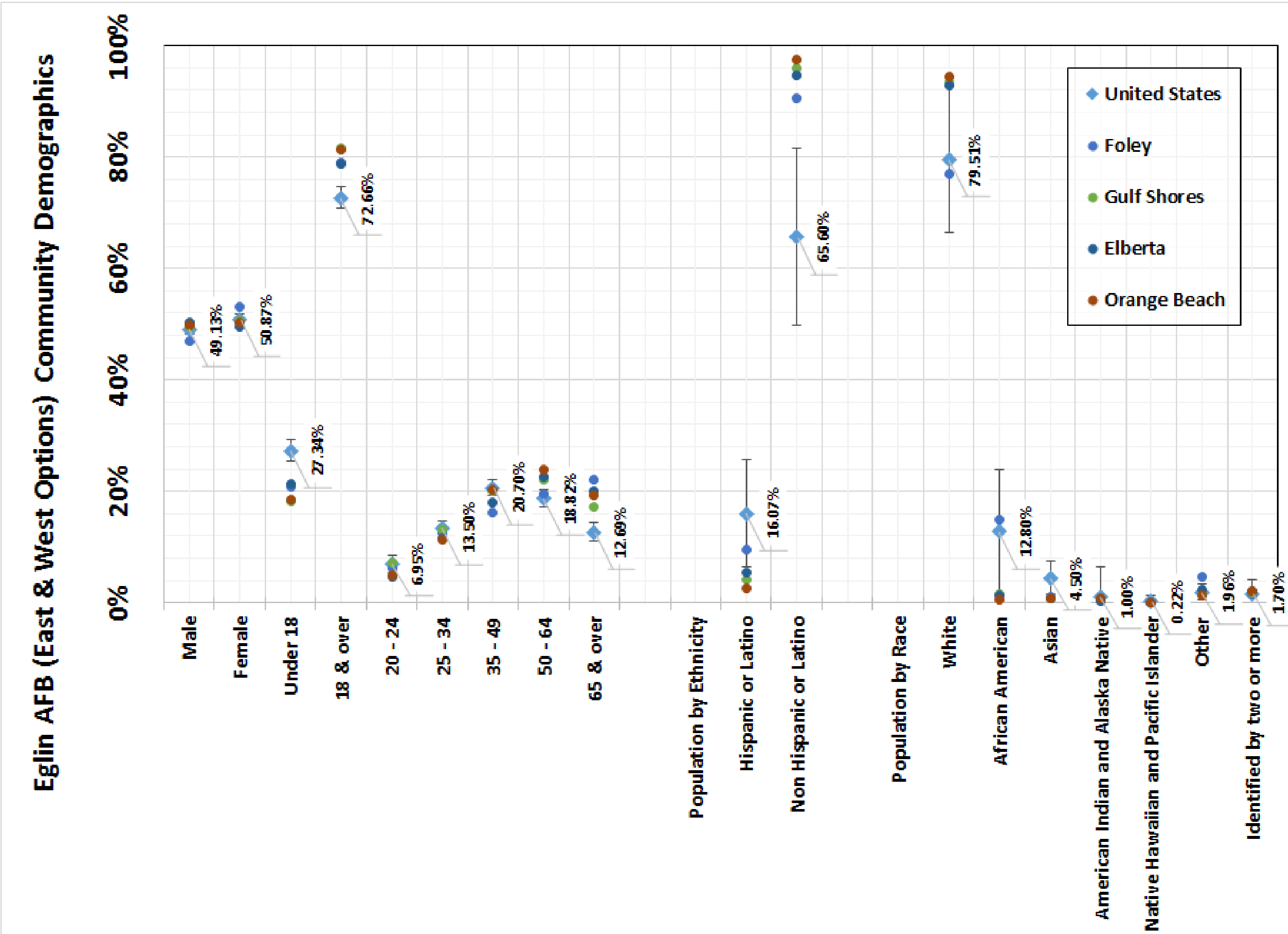


Figure B-12 Gulf Shores/Orange Beach, AL community demographics dashboard

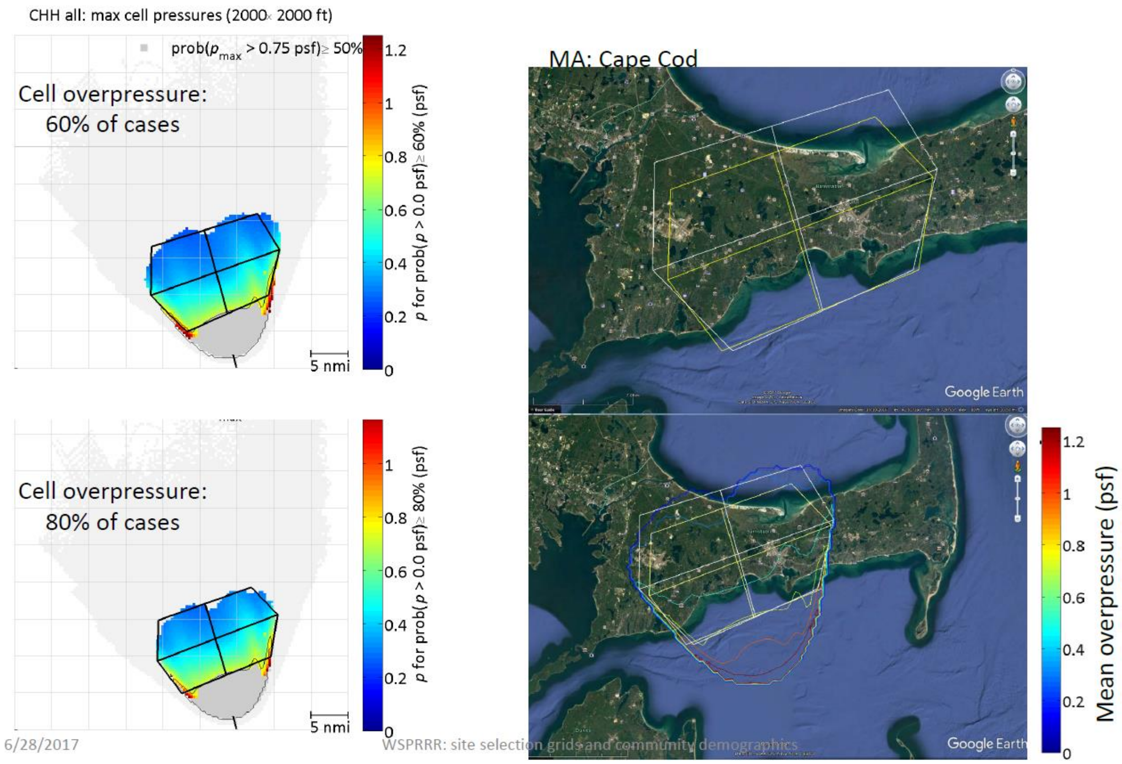
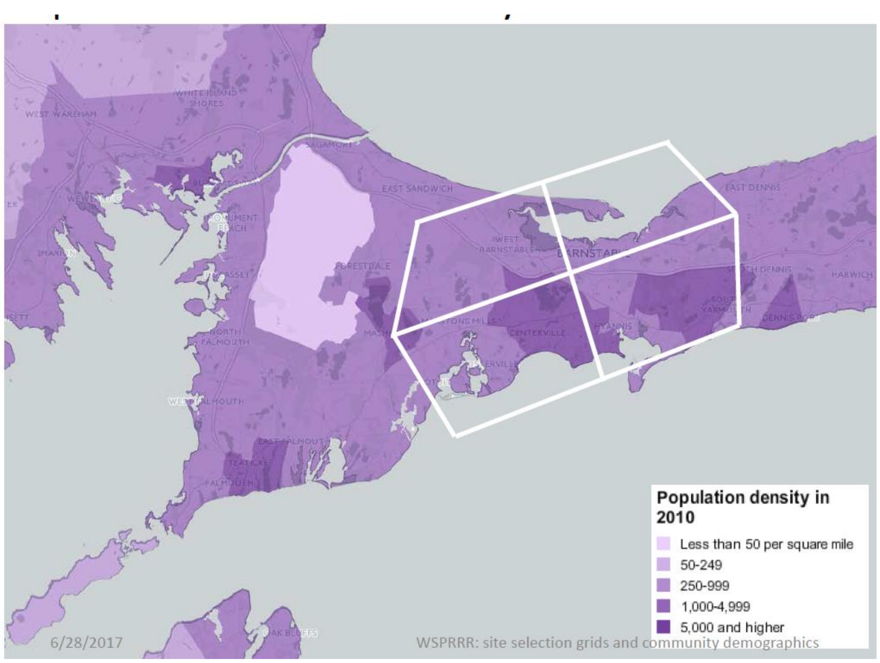


Figure B-13 Cape Cod, MA meteorological analysis probability of low amplitude sonic boom delivery



Sandwich / Mashpee	Barnstable
Total Population	
20,675 / 14,006	45,193
Percentage	
25.88% / 17.54%	56.58%
Recruits per Community	
129 / 88	283
Targets Required	
582 / 395	1,273

Figure B-14 Cape Cod, MA community recruitment and population density

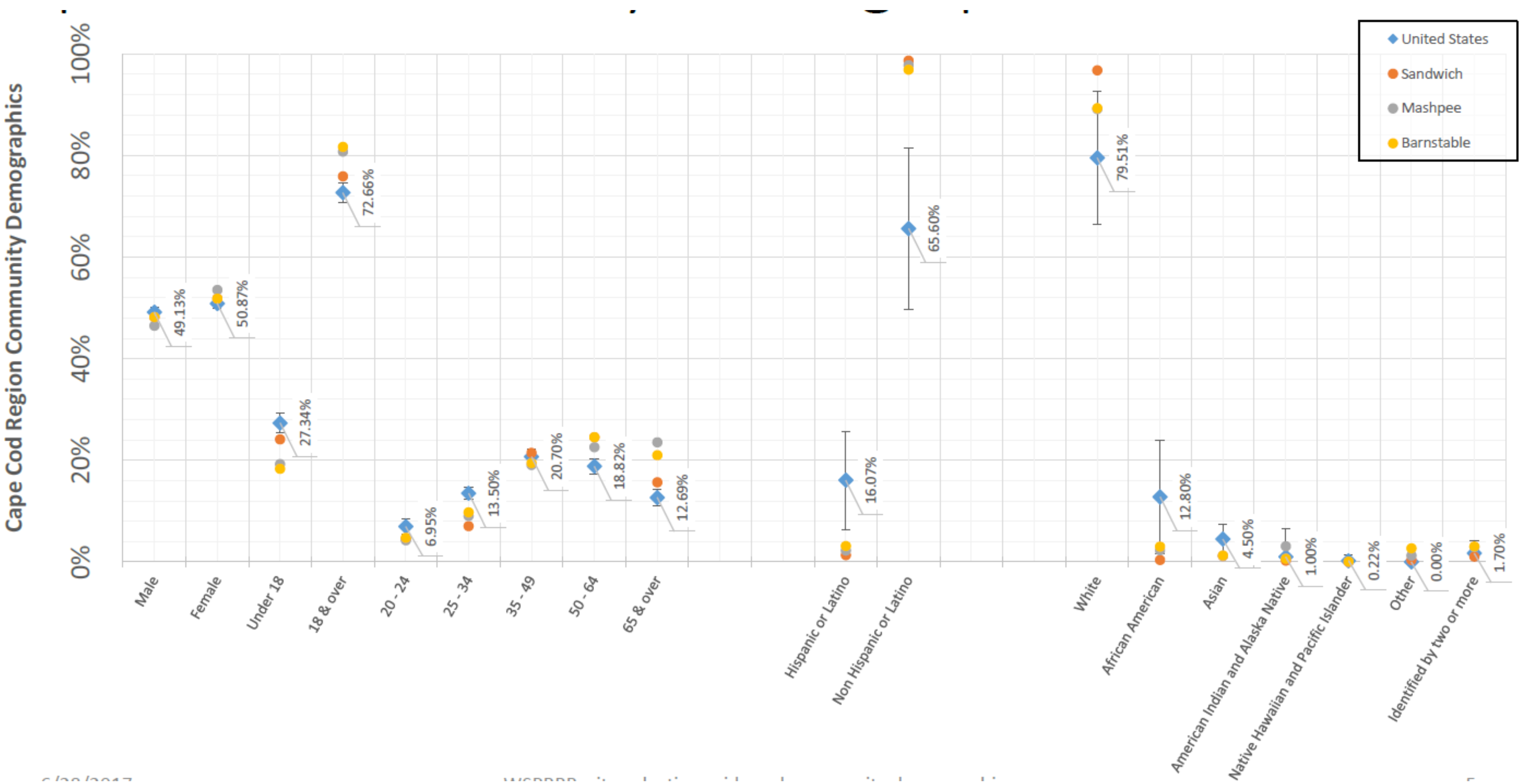


Figure B-15 Cape Cod, MA community demographics dashboard

C. Sonic Boom Weather Analysis of the F-18 Low Boom Dive Maneuver

The following pages provide Appendix C. This appendix file is provided separately from the main body of the report.

In support of community low boom test planning, a sonic boom analysis of ten years of weather data was conducted at multiple coastal regions for an F-18 conducting the NASA low boom dive maneuver (LBDM). The low boom dive maneuver involves an inverted dive where the aircraft accelerates supersonically and then pulls out above 30,000 Ft. During the dive maneuver the sonic booms arrive on both egg and crescent shaped isopemps. Due to the supersonic flight conditions and the propagation paths for the LBDM, it is generally true for the LBDM that the boom from the earlier parts of the trajectory arrives before the later part of the flight path. The influence of the local meteorological conditions on this maneuver has a striking effect on the sonic boom footprints, including the shape and location of the focal zone and the extent of the low-amplitude sonic boom carpet region.

"Sonic Boom Weather Analysis of the F-18 Low Boom Dive Maneuver" [Page & Downs, 2017] provides a description of the PCBoom sonic boom propagation results and interpretive techniques for assessing potential coastal sites for conducting dose-response testing using the F-18 dive maneuver. This briefing is provided in the following pages.

Sonic Boom Weather Analysis of the F-18 Low Boom Dive Maneuver

Juliet Page, Robert Downs

Joint Meeting of the Acoustical Society of America and the European Acoustic Association
Paper: 2pNSb8 Boston, Massachusetts 25-29 June 2017

Volpe The National Transportation Systems Center
Advancing transportation innovation for the public good

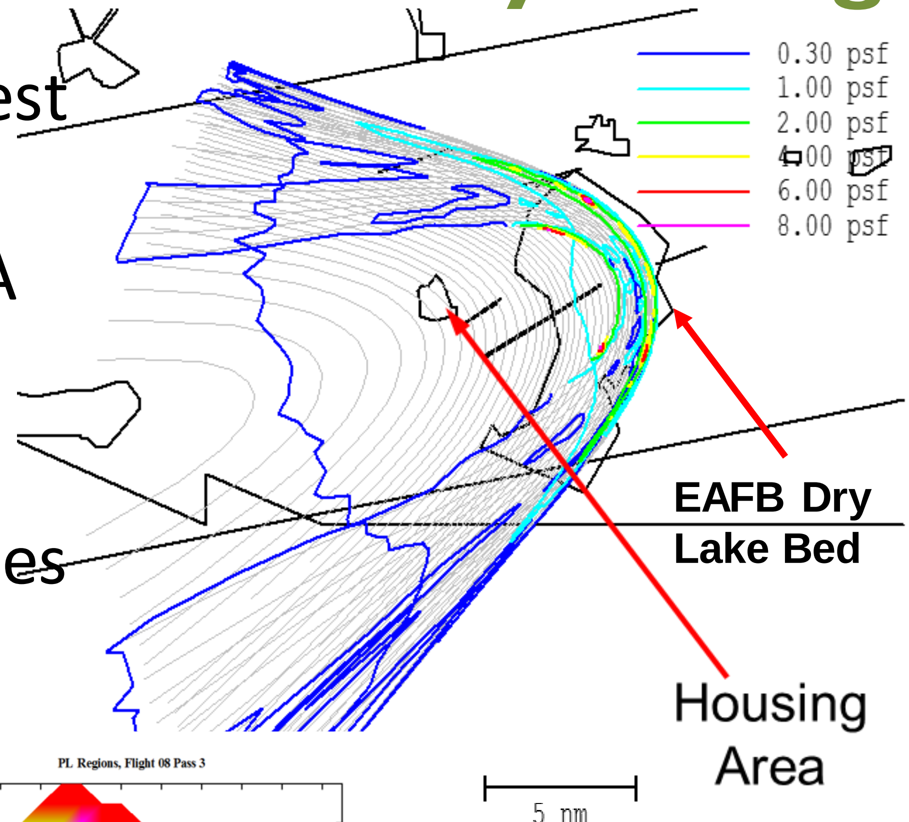
U.S. Department of Transportation
Office of the Secretary of Transportation
John A. Volpe National Transportation Systems Center

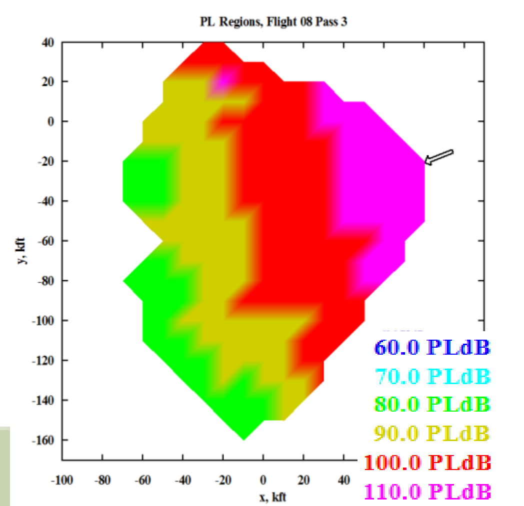
Outline

- Motivation
- F-18 Low Boom Dive Maneuver
- Meteorological Analysis
- Meteorology vs. Dive Execution Variability
- Interpretation of Results
- Conclusions
- Acknowledgements

Motivation: Future Community Testing

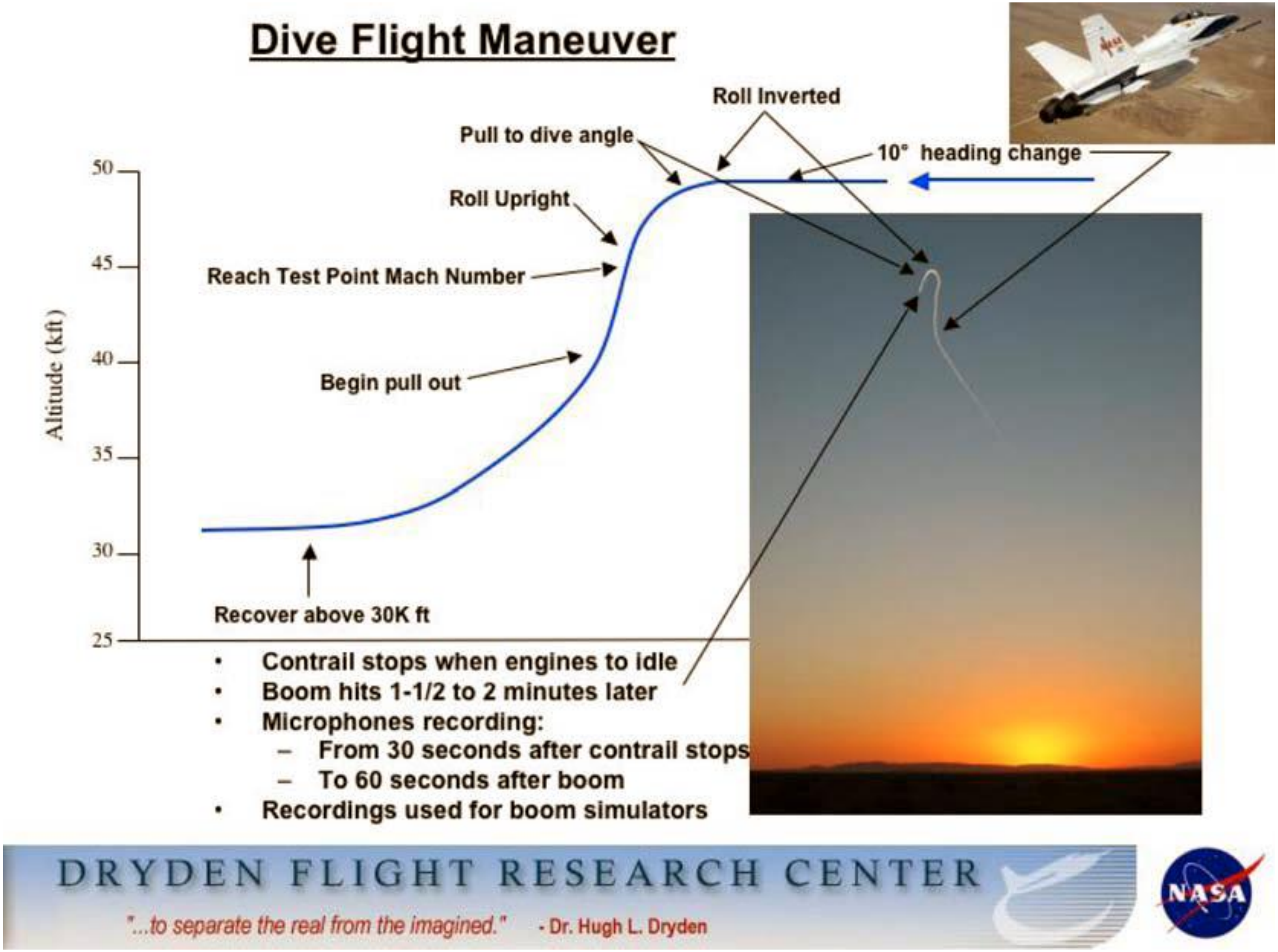
- WSPRRR: dose-response test in 2018 in a coastal community using the NASA F-18 low boom dive maneuver
- Develop Analyses techniques
- Understand meteorological effects on low booms
- Aid in site selection



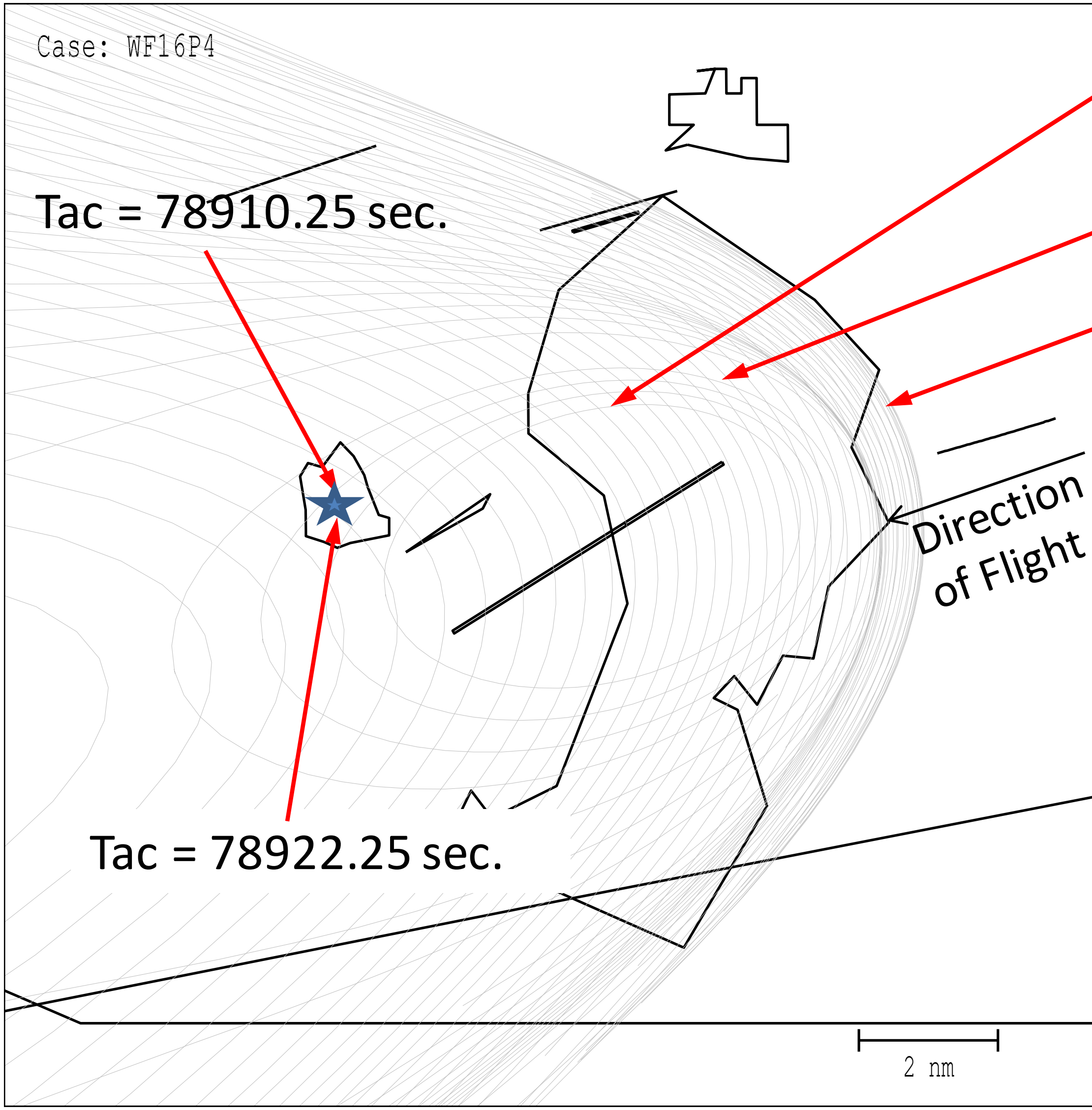


Data from WSPR 2011
NASA CR–2014-218180

F-18 Low Boom Dive Maneuver



A Closer Examination



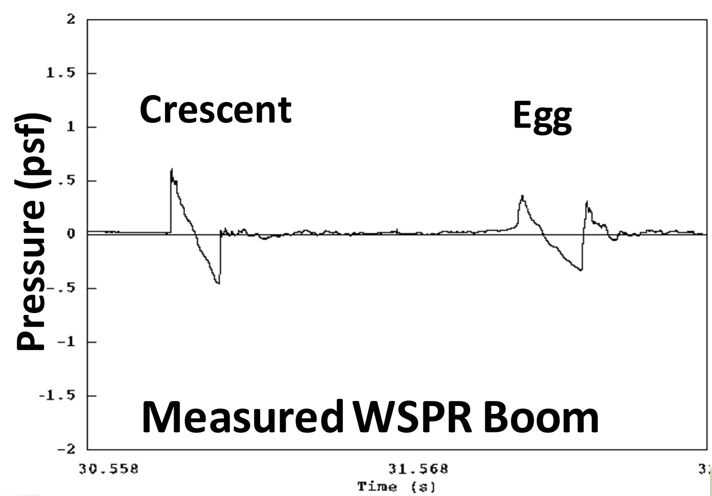
Tac = Time at Aircraft (sec)
Tac = 78909 sec.
(1st supersonic point)

Tac = 78909.50 sec.

Tac = 78915 sec.

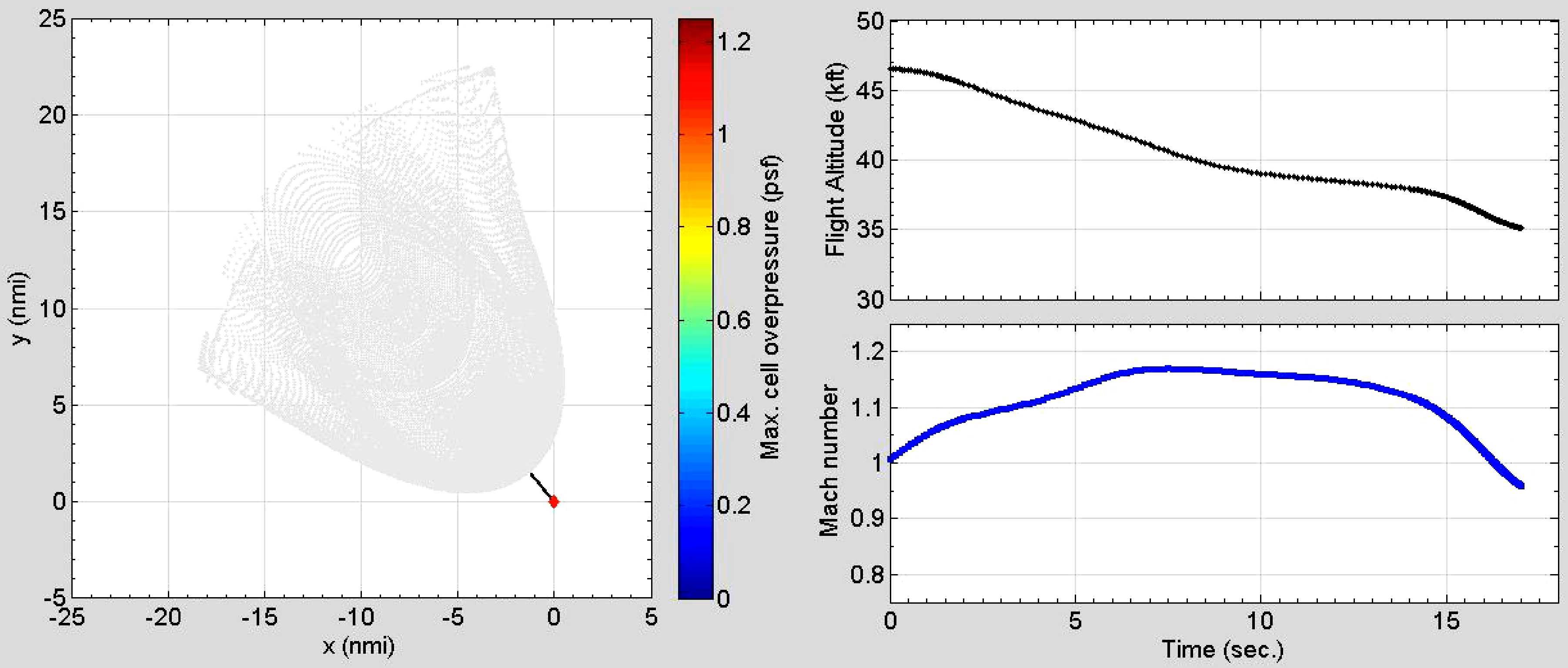
Two carpet boom regions:

- Early “eggs” as aircraft is pointing down
- Customary crescents later on
- Boom arrival times in overlap area much closer than generation times



WSPR Flight 16, Pass 4, Boom 65

Sonic Boom Animation

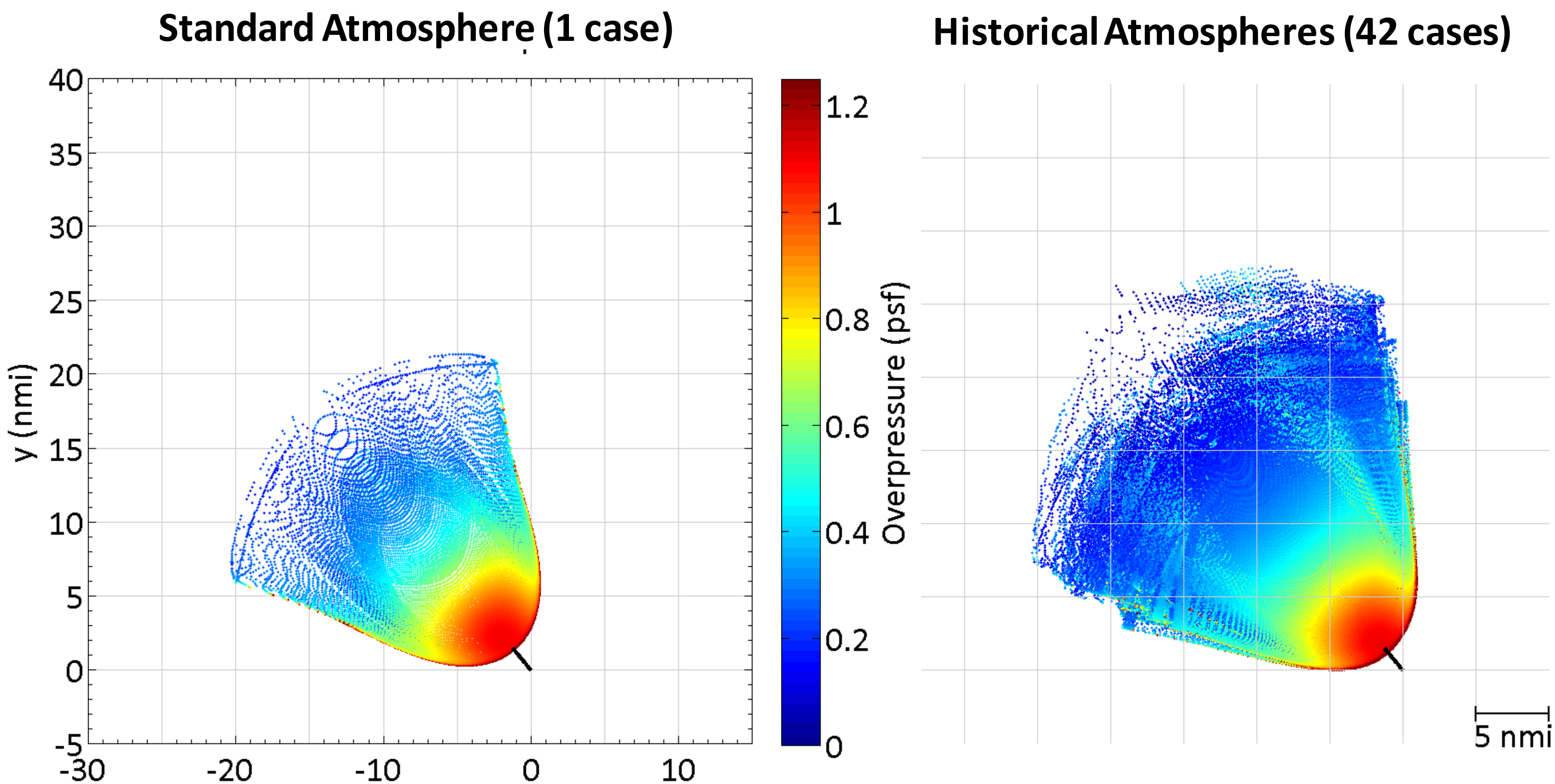


Meteorological Sonic Boom Analysis

- Analysis computed using PCBoom
- Historical meteorological data for candidate sites for the potential months of interest: August – November
- Vectorized Template F-18 Low Boom Dive Maneuver
  - Location / Orientation dependent on geography
  - Dense trajectory to provide adequate coverage
- Basic PCBoom footprints computed (psf metric)
- Molecular relaxation not included in analysis

Overpressure Comparison: Ray Ends

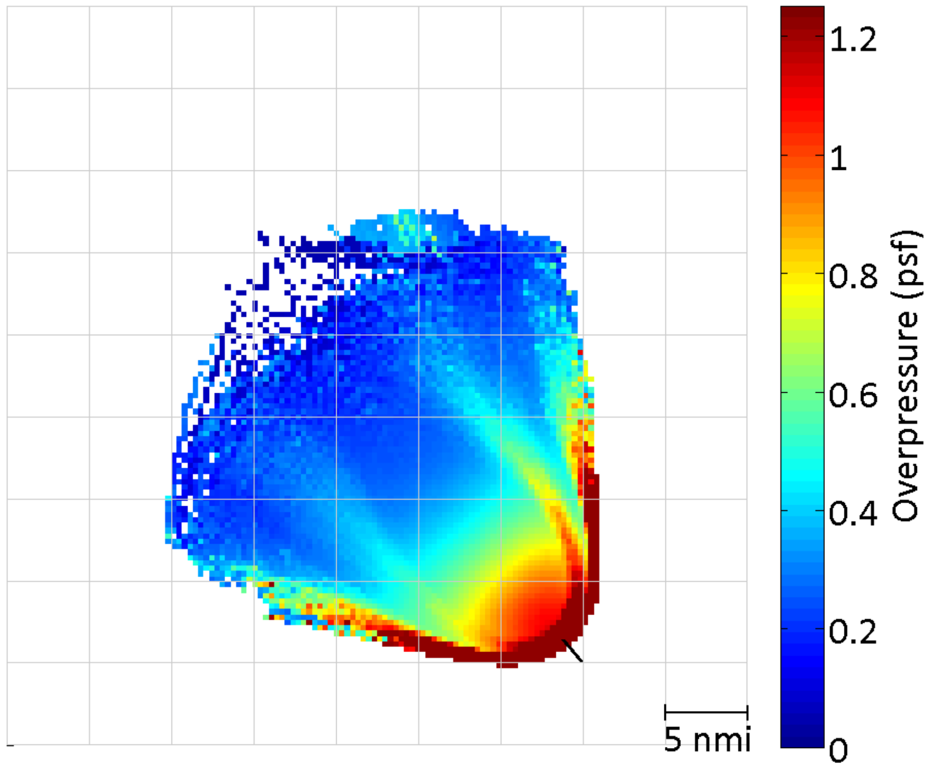
- Run PCBoom using historical weather data: Measured at 00Z and 12Z. Showing 1st, 5th, 10th, …, 30th of Aug – Oct 2016
- Combine footprints into one dataset



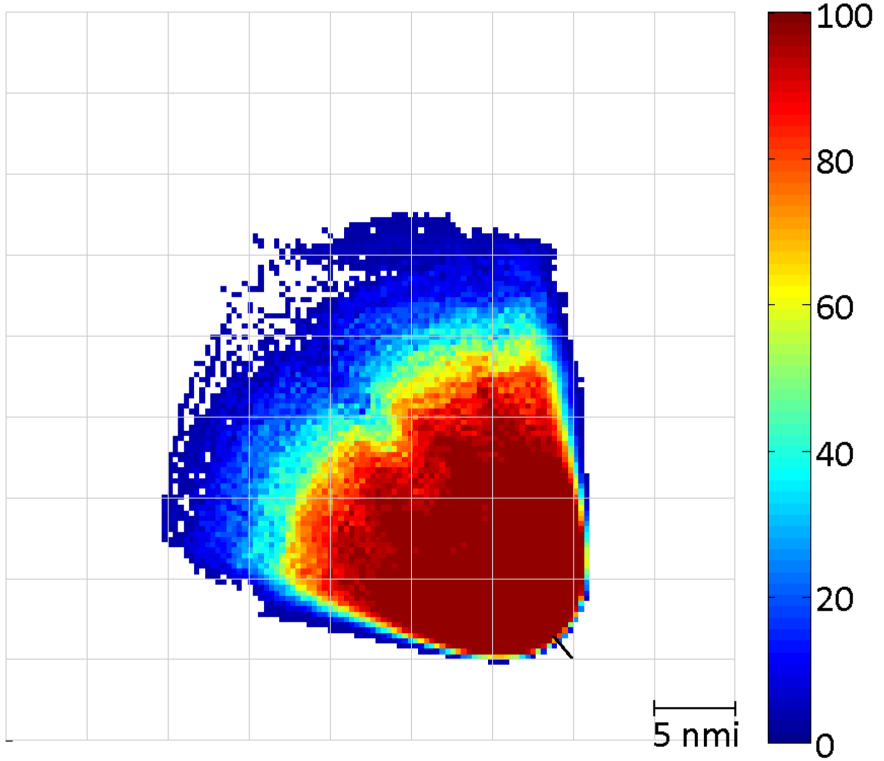
Grid Cell Examination

- Partition dataset into 2,000 × 2,000 ft cells, and extract maximum cell pressure observed for each weather instance
- Compute Boom Percentage as relative number of times each cell recorded a non-zero overpressure

Max Cell Overpressure: 2000x2000 Ft Grid



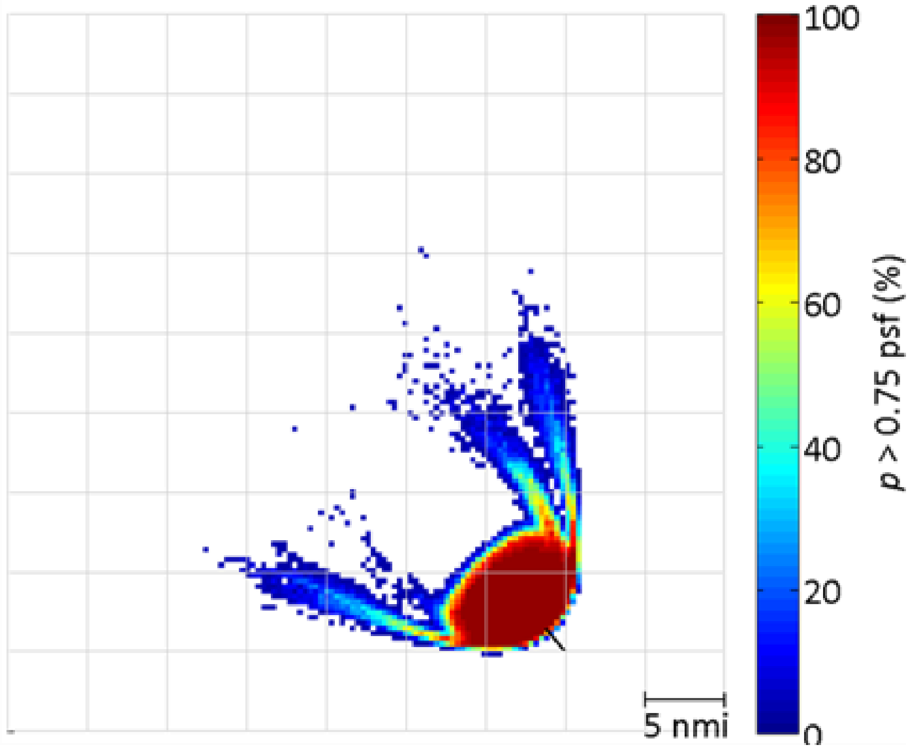
Non-zero Boom Percentage per cell



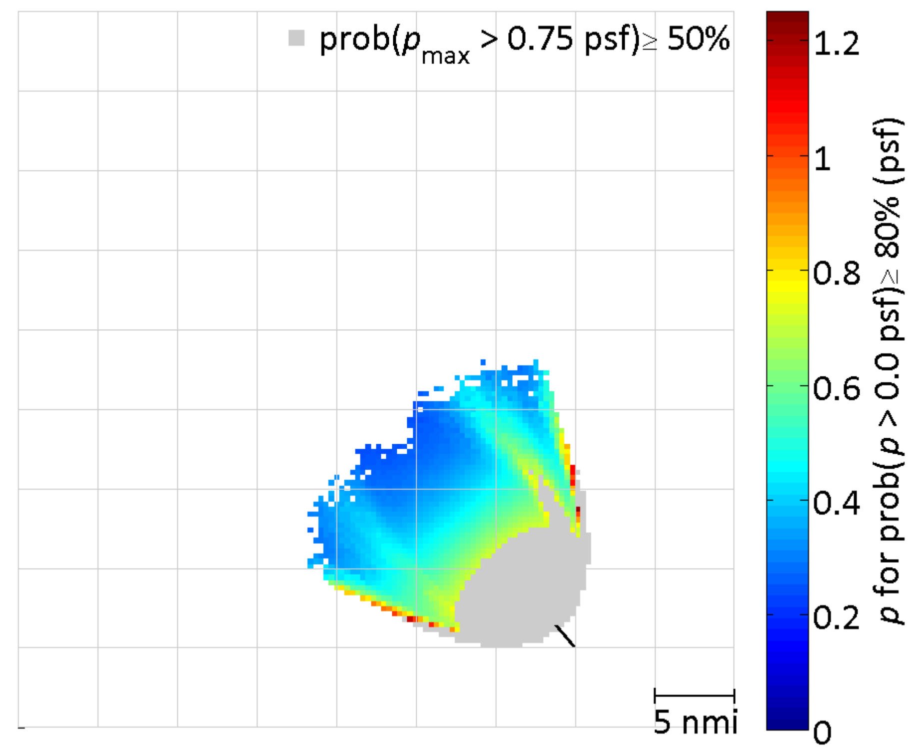
Footprint Placement / Focus Avoidance

- Compute boom percentages for high-pressure booms (>0.75 psf)
- Combine boom % results to isolate areas with
  - p > 0 psf for ≥ 80% of cases (color-mapped cells)
  - p ≥ 0.75 psf for ≥ 50% of cases (greyed-out cells)

Max Cell Overpressure: 2000x2000 Ft Grid

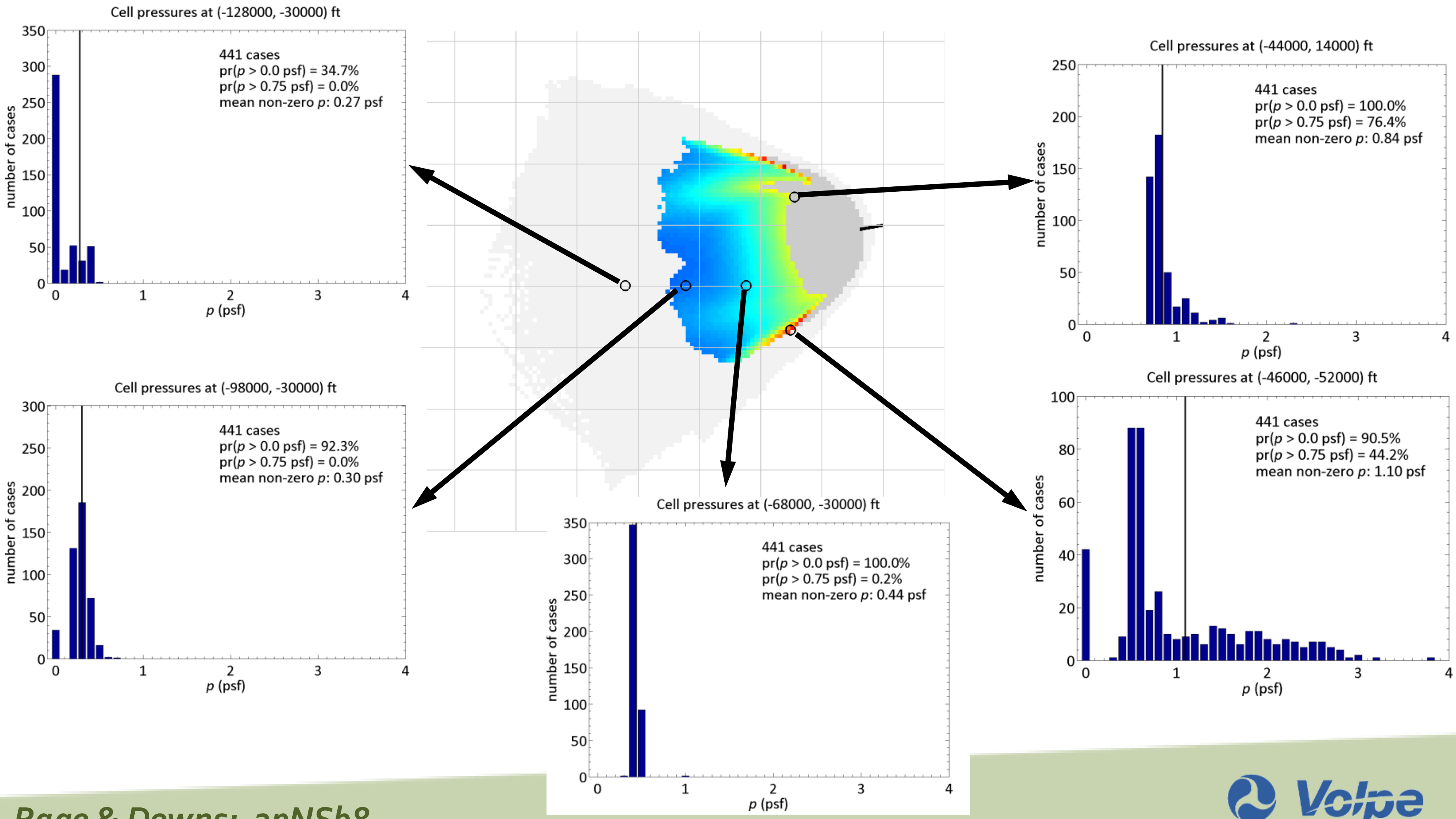


Non-zero Boom Percentage per cell



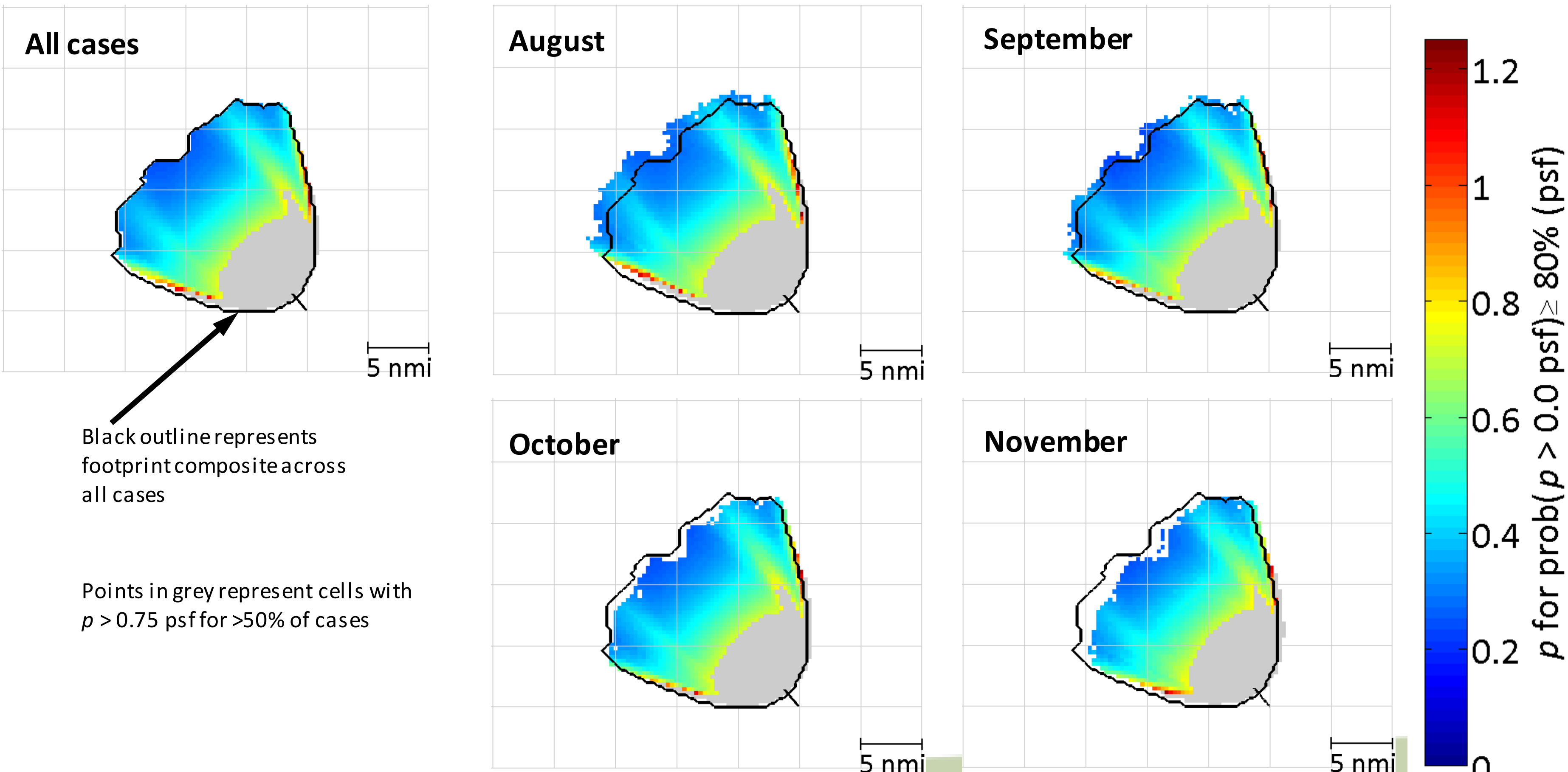
Overpressures at Selected Points

- Near the leading edge of the footprint, small numbers of high overpressure values can shift the mean cell pressure to a high value (1.10 psf) without exceeding the pr(p> 0.75 psf) > 50% criterion, as illustrated in the bottom-right probability distribution



Probability Footprint Monthly Variation

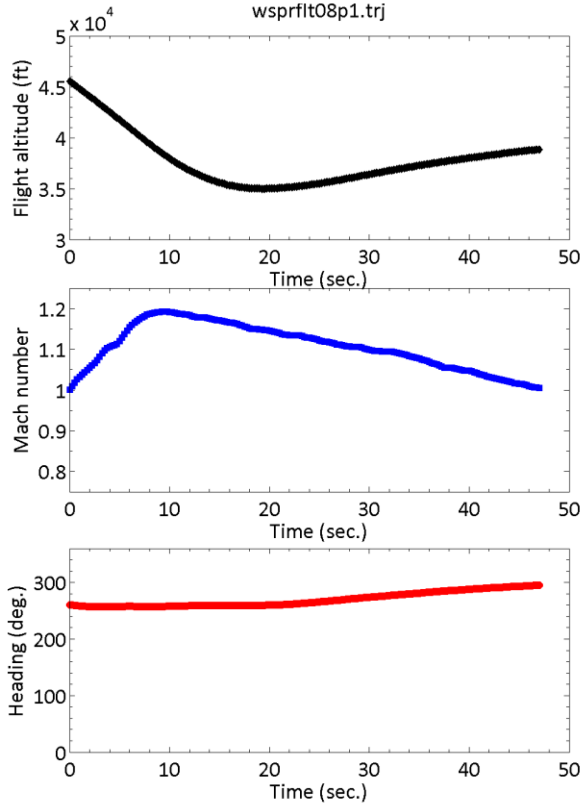
- With a large number of met cases (605 PCBoom runs), it is feasible to examine month-to-month variability in useable footprint area
- Results show a moderate West to East shift from Aug to Nov.
- Missing or incomplete weather balloon data account the cases missing from a potential set of 616 cases / site.



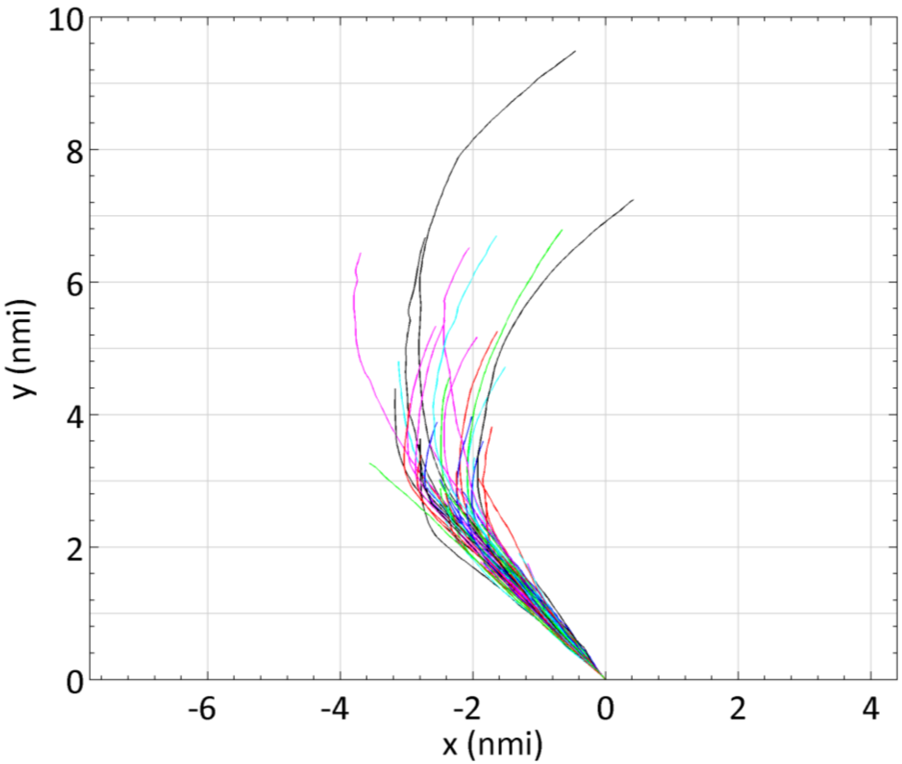
Meteorology vs. Dive Execution Variability

- 84 as-flown trajectories from the WSPR program modeled
- Flight paths re-computed to account for potential site heading
- Intermediate steps inserted in PCBoom via “TADVNCE” command

Typical WSPR flight profile

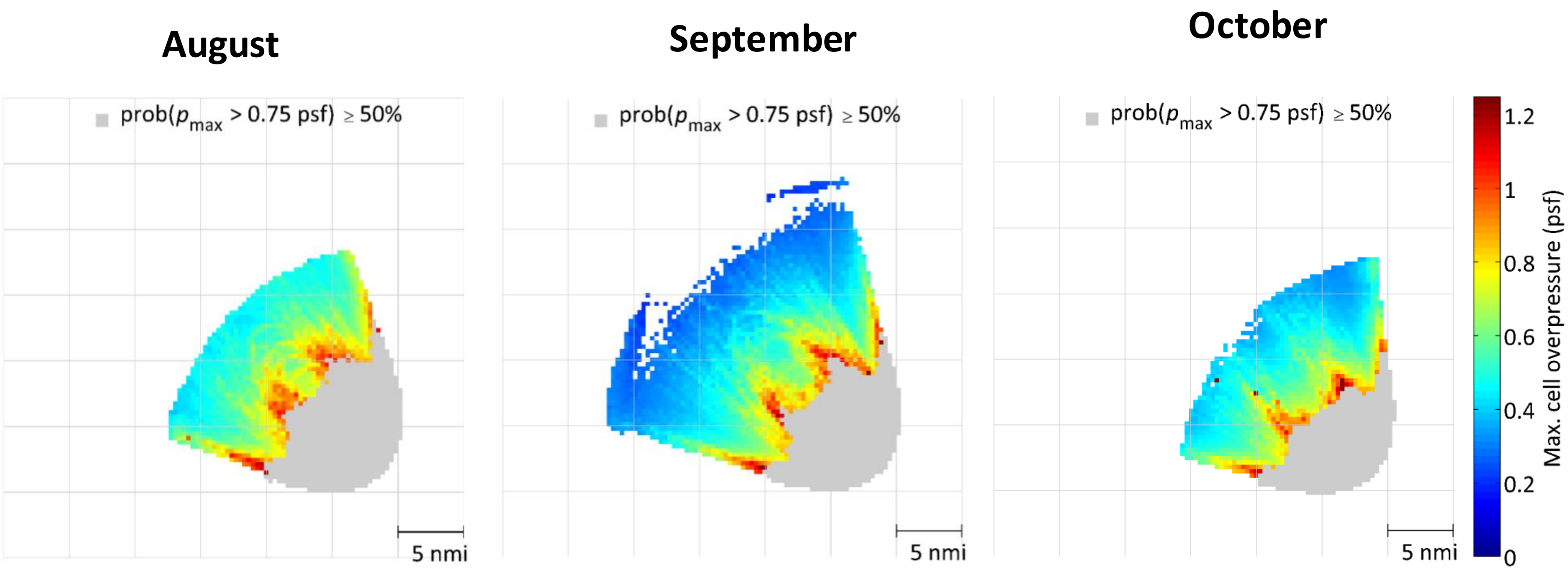


Vectored Flight Trajectories (M>1 only)

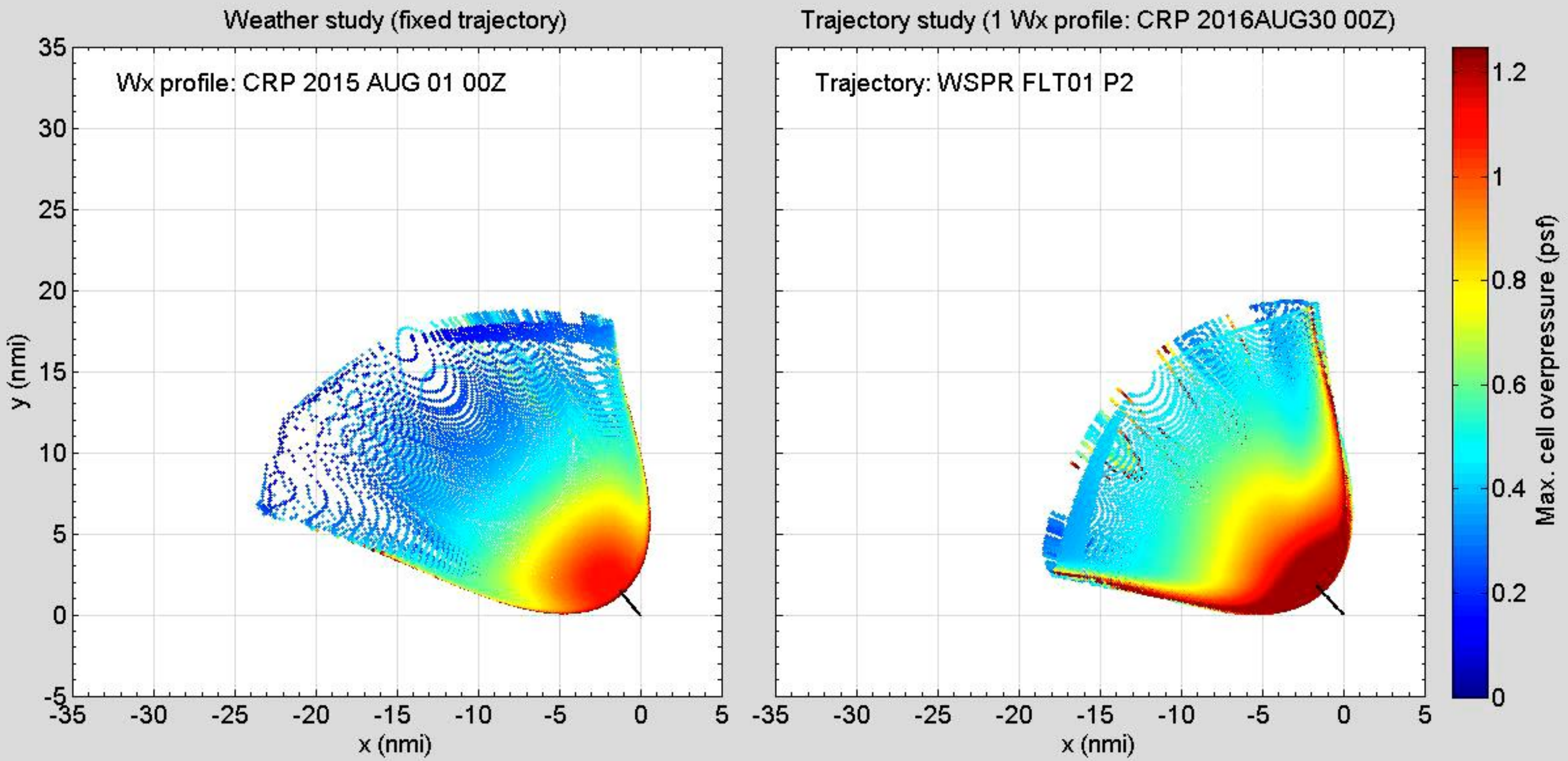


Monthly Variability using 84 Trajectories

- Select representative weather profile for Aug, Sep, Oct
- Assemble footprints using maximum pressure in 2000 × 2000 ft cell
- Cells with > 50% probability of p > 0.75 psf are grayed out
- Cells registering p > 0 psf in less than 20% of cases are excluded



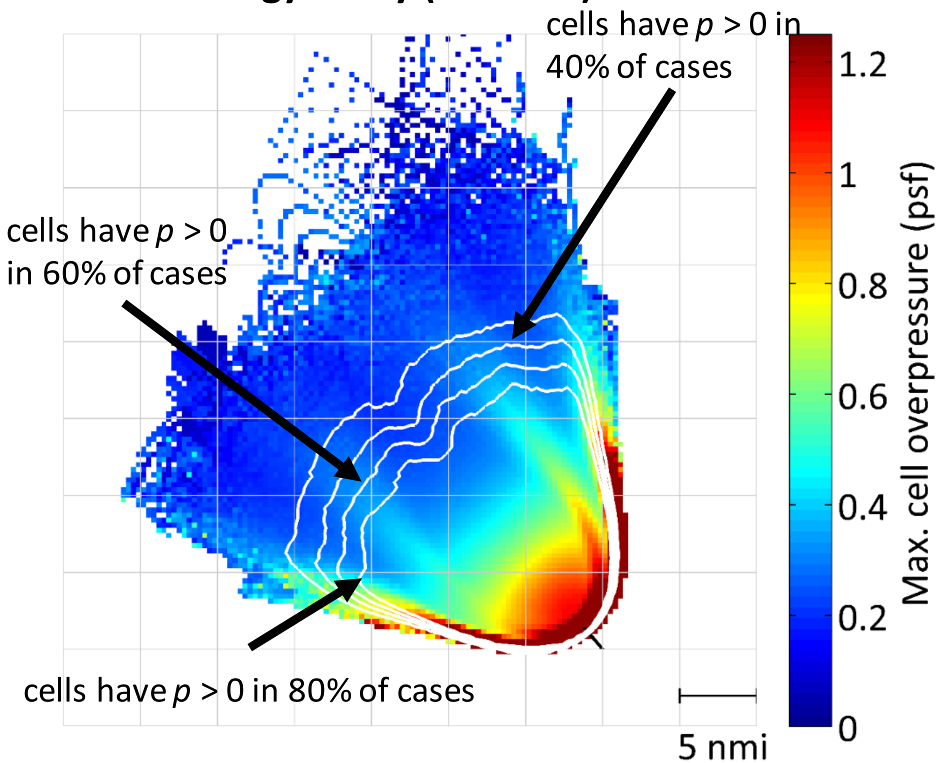
Meteorology and Trajectory Variation



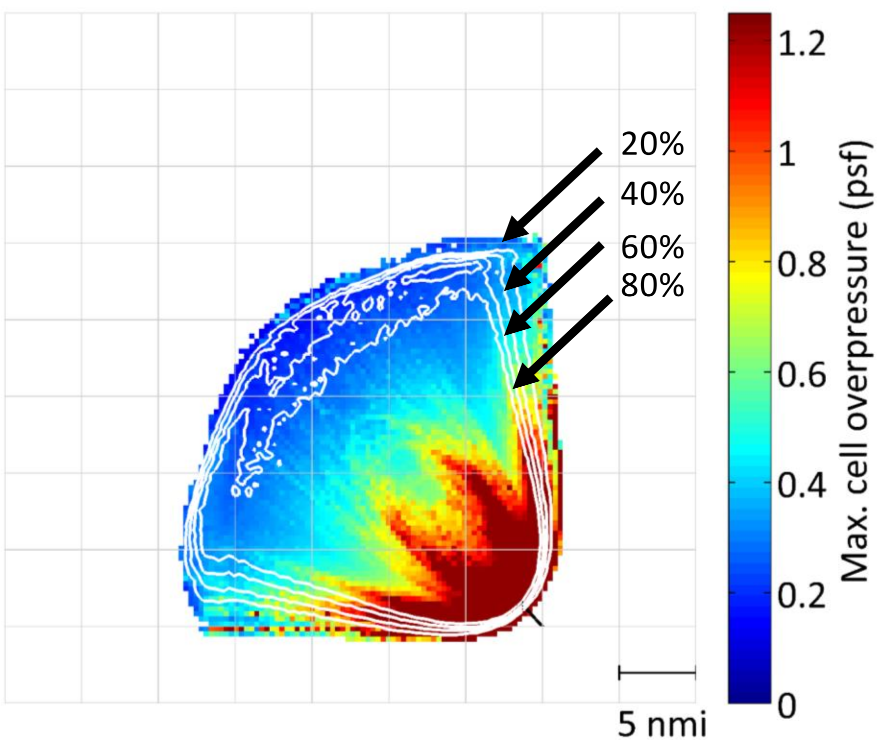
Meteorology vs. Trajectory Effects

- Changing wind conditions produces a much larger area dispersion of low-pressure cells. This is evident in the large part of the footprint characterized by cells with p ≈ 0.2 psf in less than 20% of cases.
- Boom percentage contours (white lines) are more closely spaced when weather conditions are held constant in the trajectory study.

Meteorology Study (all cases)

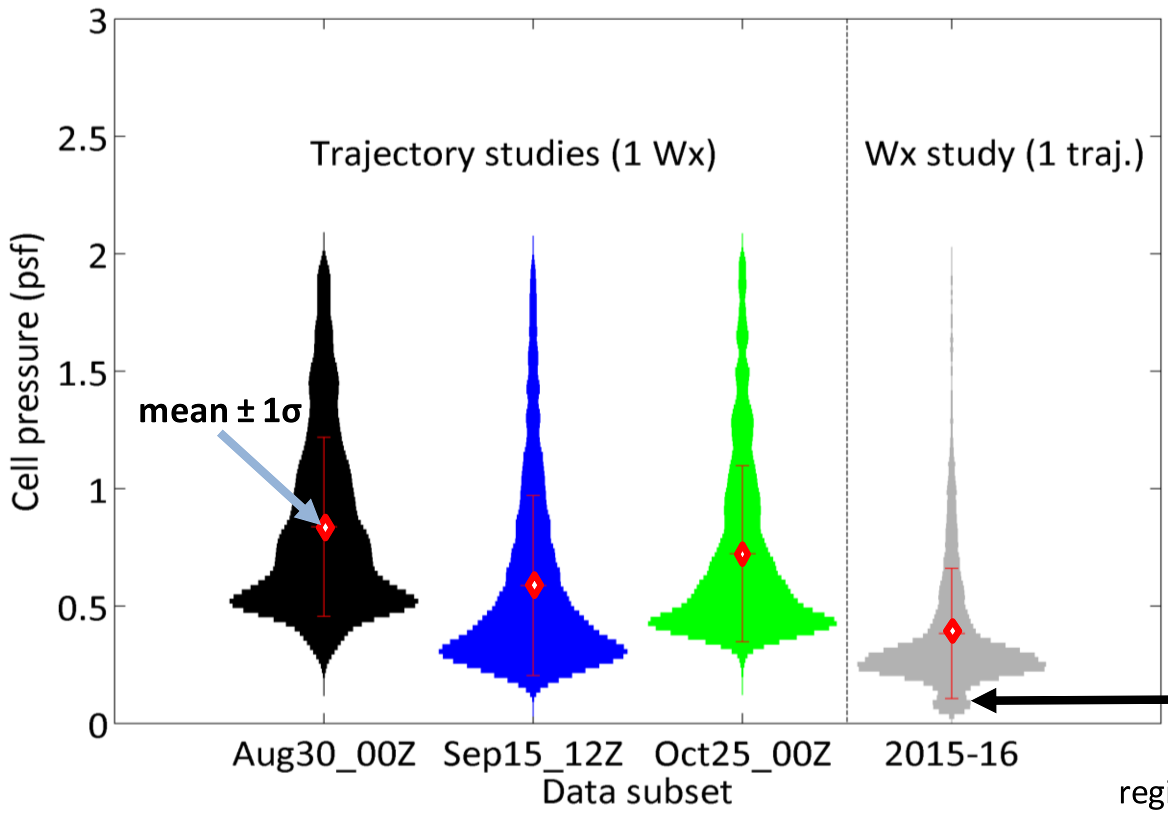


Trajectory Study (Sep 15 2016 12Z Wx)



Meteorological vs. Trajectory Effects

- For each subset of footprints, maximum cell pressure values are cataloged and their distributions can be used to illustrate the relative effects of as-flown trajectory variations and variations in weather conditions.
- Violin plots are used to visualize cell pressure distributions for four subsets of data.
- Distributions are truncated at p = 2 psf.



Data subsets and sources:

1. **Aug30_00Z trajectory study**
   - **84 as-flown trajectories**
   - **weather data 2016 Aug. 30th, 00Z**
2. **Sep15_12Z trajectory study**
   - **84 as-flown trajectories**
   - **weather data 2016 Sep. 15th 12Z**
3. **Oct25_00Z trajectory study**
   - **84 as-flown trajectories**
   - **weather data 2016 Oct. 25th, 00Z**
4. **2015-16 all**
   - **1 representative as-flown trajectory**
   - **109 weather profiles from 2015 Aug 1st to 2016 Nov 30th**

Allowing weather conditions to vary changes the distribution shape by expanding boom footprints to include regions characterized by low cell pressures.

Acknowledgements

- Research funded by NASA Langley
  - Waveform and Sonicboom Perception and Response Risk Reduction (WSPRRR) Program
  - Robert Hunt, Applied Physical Sciences Prime Contractor, Principal Investigator
  - Alexandra Loubeau, NASA Task Monitor
- Thanks to my colleagues
  - Robert Downs, Volpe – Automated PCBoom runs, analysis and graphical results
  - Lauren Jackson, Volpe – Meteorological data processing
  - Dom Maglieri, Eagle
  - Robbie Cowart, Gulfstream

Guidance and insight

D. QSF18 Detailed Test Plan for Community Response Testing in Galveston Texas

The following pages provide Appendix D. This appendix file is provided separately from the main body of the report.

NASA/CR-2018-xxxxxx

QSF-18 Detailed Test Plan for Community Response Testing in Galveston Texas

Kathleen K. Hodgdon
Penn State University, Applied Research Lab

Robert P. Hunte
Applied Physical Sciences Corp.

Juliet A. Page
Robert Downs
Volpe National Transportation System Research Center

Robert A. Cowart
Gulfstream Aerospace

Domenic J. Maglieri
Eagle Aeronautics

Kevin A. Bradley
Christopher Hobbs
KBRwyle

Trent A. Gaugler
Gaugler Consulting

Prepared for
Contract NNL15AA00C
NASA Langley Research Center
Hampton, VA
July 27, 2018

NASA STI Program ... in Profile

NASA/CONTRACTOR REPORT-2018–xxxxxx

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Trent A. Gaugler
Gaugler Consulting

Prepared for
Contract NNL15AA00C
Jonathan Rathsam (Ph.D.)

National Aeronautics and
Space Administration
Langley Research Center
Hampton, VA

July 2018

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Jonathan Rathsam, NASA Technical Monitor

Larry J. Cliatt, II, NASA Armstrong Flight Research Center Point of Contact

This report is available in electronic form at http://

Contents

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Acronyms

Abbreviation	Term
ABS	Address Based Sample
ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
ARMD	Aeronautics Research Mission Directorate
ATM	Automatic Transaction Machine
CAEP	Committee on Aviation Environmental Protection
CDMA	Code division multiple access
CDNL	C-weighted Day-Night Noise Exposure Level
COAMPS	Coupled Oceanographic Atmospheric Mesoscale Prediction System
COAMPS OS	Coupled Oceanographic Atmospheric Mesoscale Prediction System On Scene
dBA	A-weighted Decibels
dBC	C-weighted Decibels
DNL	Day-Night Noise Exposure Level
EAFB	Edwards Air Force Base
EDA	Exploratory Data Analysis
FAA	Federal Aviation Administration
GSM	Global System for Mobile Communications
ICAO	International Civil Aviation Organization
LBDM	Low Boom Dive Maneuver
LBFD	Low Boom Flight Demonstrator
LLZd	Zwicker loudness levels in phons, for diffuse incidence, calculated using a time constant of 70 msec and averaging across the two peaks.
LLZf	Zwicker loudness levels in phons, for frontal incidence, calculated using a time constant of 70 msec and averaging across the two peaks.
MAC	Media Access Control
METARS	World Meteorological Organization surface weather reporting format
NQ	FAA Noise Quest website hosted by Pennsylvania State University (http://www.noisequest.psu.edu/)
PCBoom	NASA Sonic Boom model
PL	Perceived Level of Loudness(dB)
PNL	Perceived Noise Level (dB)
SBUDAS	Sonic Boom Unattended Data Acquisition Systems
SERDP	Strategic Environmental Research and Development Program

Abbreviation	Term
SIGMETS	Significant Meteorological Event reporting format
SIM	Subscriber Identity Module
SMM	Social Media Monitoring
TAF	Terminal Aerodrome Forecast
TCPA	Telephone Consumer Protection Act
USPS	United States Postal Service
VPN	Virtual Private Network
WSPR	Waveforms and Sonic Boom Perception and Response
ZDNL	Z weighted Day-Night Sound Level

1. Introduction

This document serves as the test plan for an experimental flight test recently announced as NASA's Quiet Supersonic Flights 2018 (QSF18) and scheduled for November 2018 over Galveston, Texas. The effort is funded under Phase 2 of the Waveforms Sonic Boom Perception and Response Risk Reduction (WSPRRR) project and will use a unique supersonic dive maneuver to correlate human annoyance response with low level sonic boom noise in a community setting. Designed specifically to evaluate remote aircraft basing and operations, community engagement, acoustic measurements and community annoyance surveys, QSF18 provides an additional practice session on research methods in advance of community-scale response testing using the purpose-built Low-Boom Flight Demonstrator.

2. Background / Previous Efforts

On April 3, 2018 NASA announced the awarding of a $247.5 million contract to build the Low-Boom Flight Demonstrator (LBFD) supersonic test plane that is designed to significantly reduce sonic booms and ultimately deliver a "sonic thump." From 2022 to 2025 flight tests will be conducted in the vicinity of four to six cities around the U.S to assess how the quieter booms are perceived by residents. Test results will be shared with the Federal Aviation Administration and other aviation authorities around the world in support of regulatory change that eases the current restriction of commercial supersonic flights over land. Such flights have been banned over the U.S. since 1973, largely due to concerns about sonic booms.

A wealth of activities aimed at providing the basic information necessary to allow for these overflights have been ongoing since the turn of the century. In 2011 NASA funded the Waveforms and Sonic Boom Perception and Response (WSPR) Low-Boom Community Response Program Pilot Test [Page *et al.,* 2014]. This test was conducted over Edwards Air Force Base in California in 2011 and was designed to test and demonstrate techniques to gather data relating human subjective response to multiple low amplitude sonic booms. Such a test could not have been accomplished without the development of the F-18 Low Boom Dive Maneuver (LBDM) by NASA/AFRC (Hearing *et al.,* 2005). Shaped low boom signatures designed into the LBFD are not producible by any of today's supersonic aircraft, however the LBDM provides a reasonable surrogate for the purposes of developing testing protocols and reducing future LBFD dose-response gathering program risk.

WSPR was in essence a practice session for further wider scale testing on "non-acclimated" communities, i.e. community settings not routinely familiar with hearing sonic boom noise. Non-acclimated community testing will introduce many challenges not encountered at EAFB, e.g. off-range focus/climb signature placement, undefined participant mobility, wide area objective measurement, and diverse community dynamics including the absence of a predisposition to aircraft noise; willingness to participate in the experiment; safety and security, and a host of other issues that present risks to the success of the experiment and the attainment of certification for supersonic overland flight.

Knowledge of the boom exposure the subjects will experience is paramount to their response. It has been established that the turbulence in the lower layers of the atmosphere can result in significant distortions of the designed boom exposure. These happenings are statistical in nature and until recently prediction of such occurrences was not available. Significant progress has also been made in this area. The NASA Sonic Booms in Atmospheric Turbulence (SonicBAT) Program was successfully completed May 2018. This three year effort was aimed at defining the effect of turbulence on sonic boom signatures through the execution of flight experiments in which a comprehensive set of boom signatures and atmospheric turbulence data were simultaneously collected and used to develop and validate two sonic booms in turbulence prediction codes, a numeric turbulence model code and a classic turbulence model code. These two codes were used to assess the effects of turbulence on the loudness of shaped sonic booms predicted from low boom aircraft designs (Bradley et al. 2018).

In 2015 NASA tasked Applied Physical Sciences (APS) with developing a conceptual plan for future testing with the NASA LBFD. The objectives of the Community Response NRA Phase 1 included (1) the creation of a conceptual sonic boom community test within the contiguous United States, (2) identification of key risks and development areas associated with the planning, execution and data analyses of such testing, and (3) propose risk reduction activities in priority research areas that require further understanding prior to executing the Galveston tests. The results from this Phase 1 study provides the basis for a low-amplitude sonic boom subjective noise test in four to six different regions in the United States, presents a perspective on risk identification, prioritization and mitigation, and a risk reduction plan and the identification of key risk mitigation activities and outcomes. Also included was a proposed Phase 2 effort for further exploration and mitigation of high priority risks, a test at NASA Armstrong utilizing NASA employees, and an F-18 dive test over a non-acclimated community.

In August of 2016 NASA funded the Phase 2 effort proposed by APS. A plan to conduct a Low Boom Flight Demonstrator Community Response Pre-Test was submitted to NASA/AFRC in January 2017. The intent of this test was to evaluate mitigation methods for risks related to the accuracy in determining the location of a subjective response from a participant at the time of a sonic boom event, the effectiveness of our subjective survey methods, and our cellular networking of acoustic data collection equipment across the full extent of the sonic boom footprint. These tests were also designed to provide for Lessons Learned regarding the control and placement of the boom footprint from the F-18 LBDM within the test control area containing the ground acoustic array and test subjects, communications, instrumentation setup and operation, time to setup, etc. The test was successfully conducted from 8-12 May 2017 and provided valuable lessons learned and validated key data collection methods planned for the risk reduction Quiet Supersonic Flight Community Response Test (QSF18) scheduled for November 2018.

Activities related to the Community Response Test are well underway and the down selection of a number of communities has been made. Galveston, TX. has been found to be the most suited. NASA/AFRC has instituted weekly WebEx gatherings designed to put into effect plans for the boom overflight. Visits to the area have been made, measurement sites documented, recruiting has begun, and public announcement made on the upcoming event (Button, May 2018)

3. Test objectives

QSF18 provides the first flight test for this new "low-boom" noise source over a non-acclimated community and an opportunity to gather data demonstrating methodology to correlate human annoyance with low level sonic boom noise. The assessment of community noise impact from civilian supersonic flight over land using a low boom flight maneuver includes the investigation of relevant objective and subjective variables that affect the given noise environment. Objectively, it should adequately characterize the noise environment and identify an appropriate metric to represent it from empirically and/or analytically-derived measures. Subjectively, it should assess aspects of community impact including annoyance, attitudes, and the extent to which the noise interferes with daily activities. Correlations between objective and subjective variables can identify methods and metrics that relate to the subjective perception. Measurements of the single event and estimates of daily cumulative noise levels and associated survey responses are being gathered to provide a comprehensive dose response data set. Additionally, the test provides an opportunity to engage the public on matters related to this and future testing using LBFD, including interface with public officials, emergency responders, local media, and the public at-large. Finally, conducting F-18 research flight operations from yet another remote location offers NASA's AFRC Flight Operations Test Planning Team the chance to further explore interface with regional air traffic management services as well as coordinating logistical needs for remote aircraft basing. The findings of this effort will provide lessons learned and further improve research methods for future community-scale response testing using the purpose-built LBFD.

4. Success Criteria

4.1 Number of flights and booms

The noise plan includes eight flight days over a 10-day period distributed over two weeks with another two backup flight days reserved for any inclement weather. The plan includes the potential for 8 booms maximum per day, with an average of three flights daily. There is at least 20 minutes of separation between booms, allowing for 2 to 3 booms per flight. With a sufficient number of recruits enrolled as participants, it is anticipated that generating 32 booms over the course of the field test would be adequate success criteria. Consider that in the power analysis simulations outlined in Sections 5.3-5.4 where 48 total booms were analyzed in a manner that was consistent with the analysis conducted during WSPR2011. If we decrease this by 33% to 32 booms, we will have a commensurate reduction in overall sample size. According to Figure 5-2, a reduction of the 400 anticipated recruits to 268 would result in power near the 60% mark for discovering the dose-response relationship.

4.2 Recordings per boom

Recording equipment to be deployed includes: twelve Sonic Boom Unattended Data Acquisition Systems (SBUDAS), each with two recording channels and five single channel Sonic Pressure Integrated Kit Electronics (SPIKE) systems. Ideally each boom delivered to the community would be recorded by all instruments resulting in 17 recordings per boom, however given the variability of the LBDM footprint it is anticipated that for some flights some of those instruments west of Galveston on the Texas mainland are beyond cutoff and may not receive a sonic boom signal. The Noise Dose Design described in Section 8 calls for four distinct boom footprints across the community; the number of recordings and where it is critical for these recordings to be performed are described in Section 12.4.

4.3 Response rates required for single event and end of day surveys

Two prior studies were reviewed to identify the observed response rates. This range of response rates was used in the determination of sample size for this study. The 2011 WSPR study (Page et al, 2012) and a recent 2018 study of AFRC personnel response to sonic booms conducted in 2017 were reviewed. A review of data from these two studies indicate that response rate can vary from ~7% to 45% on average. Given these differences several values were explored for average response rate in the range of what was observed during the previous studies. A conservative value of 7% was selected for the sample size estimation to ensure adequate capture of data to support statistical analysis.

4.4 Required percentage of subject locations positively identified

Participants provide both their home and work locations on the background survey. They are given the opportunity to enter their exact location when submitting their single event responses. The automated GPS location and mapping is provided as a convenience, but is not a necessity to determine location. For most situations, the respondent should be able to provide their current location as needed.

There are 52 single event booms in the design. The location should be identified at least 50% of the time automatically, with the addition of self-reported locations will increase that location identification rate to 95%. If we recruit 400 respondents we should have sufficient data if we are successful in delivering 32 single event booms. We are assuming that the identification of the location will not be an issue, as we are not relying on automated methods to report it.

5. Subject Recruitment Plan

5.1 Recruitment Strategy

The target population is residents exposed to low booms created by the F-18 dive maneuver, whether they are at home or away from home. The target community will be divided into grid cells under the boom footprint and census data will be used to assess demographic information across the geographic regions.

The recruiting strategy implements a modified version of the Tailored Design Method (TDM) (Dillman, Smyth and Christian, 2009) that features use of a web enabled survey platform. The use of a small pre-incentive is recommended in the TDM recruiting strategy and can increase response rates by 10 to 15%.

Once the areas under the sonic thump footprint are determined and the demographic distribution of the community is assessed, we will sample from the population utilizing a targeted Address Based Sampling (ABS) approach. ABS samples are based on the United States Postal Service Delivery Sequence File, which is regularly updated based on postal carrier reports.

5.2 Methodologies for stratification and sample selection

The PSU Survey Research Center is obtaining the potential sample using ABS from Survey Sampling International (SSI). Typically, Zip Codes are used to define a survey community, but smaller geographies can be identified using latitude and longitude. A complete list of households within the survey area will be compiled by Survey Sampling International. From this list, a systematic random sample of 4000 to 8000 homes will be selected using a random starting point and a sampling interval in order to reach the target sample size of 400 to 500 respondents. The interval would be based on the ratio of required respondents to the total number of available households in that area. The recruiting strategy includes multiple contact attempts and simple questions to maximize survey participation. Any member of the household that is qualified can enroll into the study by submitting a background survey. Questions on the background survey ensure that the potential respondents both lived and worked in an area under the intended flight path.

Stratification by region will be implemented for enrollment into the reminder/non- reminder groups. We will identify recruits by region, and then randomize assignment to reminder/non-reminder across the region. This will ensure that we have it distributed across the communities.

5.3 Sample size justification

To evaluate the sample size required, we implemented an approach similar to the analysis outlined in "Research Methods for Understanding Aircraft Noise Annoyances and Sleep Disturbance", released by the NAS in 2014. As such, data simulation of varying sample sizes evaluates the effect of the sample size on both precision of our estimation of important model parameters and, similarly, the power to detect significant model parameters, varying the significance of parameters under investigation. Informed guesses for the many required inputs to the simulation are obtained from the 2011 WSPR study (Page *et* *al*, 2014) and a recent 2018 study of AFRC personnel response to sonic booms conducted in 2017. Data from these events was utilized to assess:

- reasonable response rates for participants,
- reasonable values for quantities governing the dose-response relationship,
- reasonable annoyance response profiles.

A review of data from these two studies indicate that response rate can vary from ~7% to 45% on average. These studies differ from the planned community response test as follows:

- The participants were at home during WSPR 2011 or at work during the recent 2017 study of AFRC personnel. During the community response test the participants are expected to be freely mobile and busy with work/life events which may affect their response rate.

- During WSPR 2011 and the recent 2017 AFRC study, all participants were residents or employees on Edwards Air Force Base that were familiar with sonic booms and motivated to support each of the studies. One of the major objectives of the planned community response test is to engage a "non-acclimated" population in an area where sonic booms do not normally occur. We anticipate this population to provide a different response rate than what was observed during the previous studies.

- During WSPR 2011 and the recent 2017 AFRC study, the participants were exposed to some sonic booms which were louder than what is planned for the community response test. The community response test will employ sonic booms of the level anticipated to be delivered by the LBFD aircraft.

Given these differences several values were explored for average response rate in the range of what was observed during the previous studies. A conservative value of 7% was selected to ensure adequate capture of data to support statistical analysis of the current effort. This approach provides conservative estimates of statistical power and precision in the case that the response rates are higher. The WSPR 2011 effort presented boom levels comparable to the current proposed effort, and exhibited a slope of approximately 0.06 for the PL metric. Therefore, slopes from 0 (no relationship) to 0.03 are explored as a conservative estimate.

5.4 <u>Statistical methodologies for sample size</u>

Using each sample size, and true value of the slope under investigation, we simulate 100 datasets as described above to assess whether a non-zero slope is detected and the degree of accuracy of the estimated slope (Figure 5-1). According to Figure 5-2 there exists power to detect a relationship half as large as in WSPR 2011 (slope of .03 vs. .06) with a sample size of 300 (i.e. 300 total participants would detect this nearly 100% of the time, according to simulations). However, we expect far less annoyance due to low boom noise, and conservatively note that to achieve 80% power in detecting a relationship that is roughly 75% smaller (~.015), we need between 400-500 participants in total.

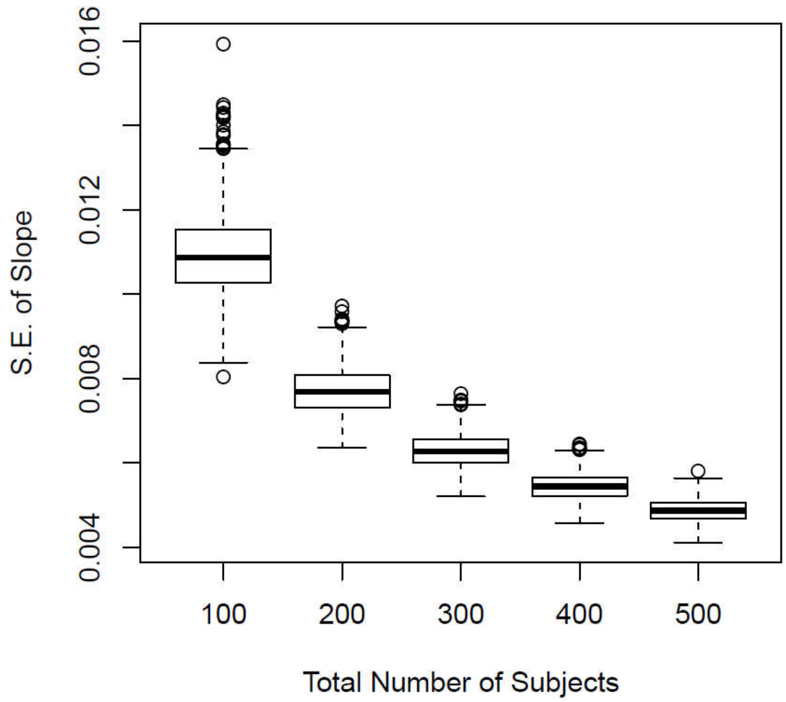

Figure 5-1. Precision for Slope with average 7% response rate.

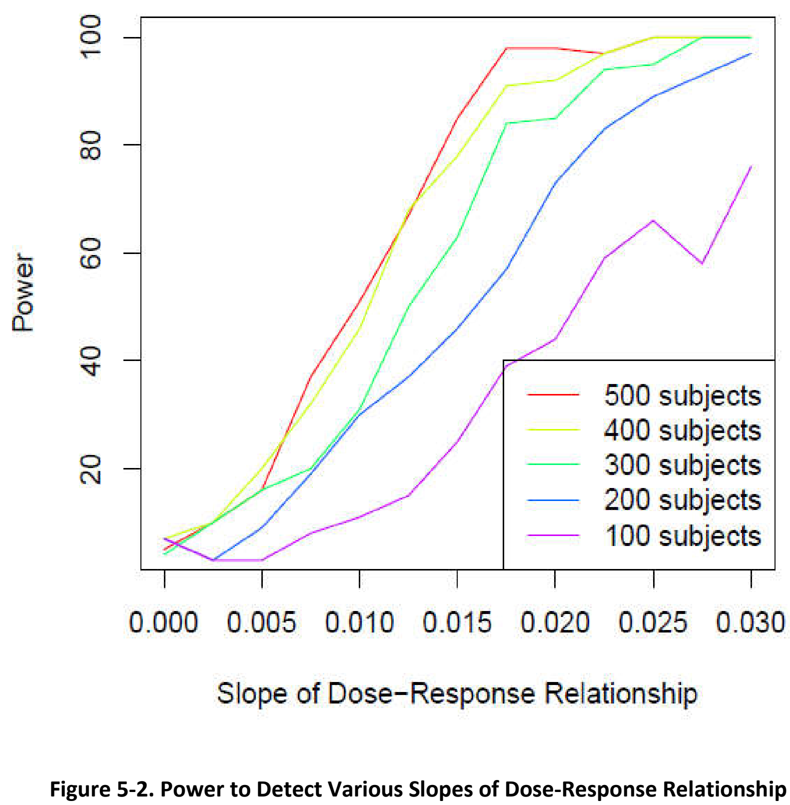

Figure 5-2. Power to Detect Various Slopes of Dose-Response Relationship as a Function of Sample Size for an average response rate of 7%.

5.5 Recruitment Schedule

In implementing a modified version of the TDM, the recruitment process will include up to 3-points of contact with potential respondents. This includes 1) a recruitment invitation letter; 2) a web-enabled enrollment link and 3) a post-card reminder.

The Recruitment Mailing includes a recruitment letter with a link for the participant to enroll in the study, and a $2 token incentive sent to all potential recruits. The letter will include information on the nature of the survey, as well as the process of data collection. The consent and background survey will provide the opportunity for respondents to provide on-line contact information (email and mobile phone), consent to contact via phone or email, and work address to ensure respondents both lives and works within the expected boom carpet. The survey questionnaires will be formatted in a mobile enabled web platform, Qualtrics, a web based survey software tool. A three day dry run will be conducted with the members of the WSPRRR team. For the dry run all participants will be treated as members of the reminder group. They will be sent daily reminders to complete the surveys and reminders throughout the day to listen and respond. The goal is to test the distribution of reminders and the ability of the team to use the survey response system.

Once the initial mailing has been sent, the practice is to wait 1 week to 10-days for responses to return, before sending the reminder postcard. This will allow for any return of bad addresses as well as any initial web completions. Bad addresses will be supplemented with new addresses, and those who complete via the web contact survey will be removed from any subsequent mailing. Each sample address will be assigned a unique ID number that will be used by the SRC for tracking purposes. All correspondence will include the ID number as well as the potential respondent name (when possible). Final data will only include ID number and identifiable information will only be used for tracking purposes and will be kept in a secure location and accessible only by the SRC. As responses come in via business reply envelope or web survey, they will be recorded daily and databases will be updated to indicate who has responded and who has not.

Approximately 1 week to 10-days after the reminder post card, a 2nd post card reminder will be sent to all non-respondents according to the daily updated data base. Approximately 2 weeks to 20 days after the final mailing, the survey will be deemed “closed” assuming all those who have chosen to complete will have done so by that time.

As mentioned above, stratification by region will be implemented for enrollment into the reminder/non-reminder groups. The reminder group will each receive the access code prior to the start of the study to confirm their receipt of the code. The non-reminder group will each receive a unique code as an email. For the single event and daily events, there will be two separate "portal" pages. The reminder group will receive a text with that URL; the non-reminder group will have an instruction email sent to them at the onset of the study. They will then use their code to access the respective surveys. The recruitment schedule is provided in Table 5-1.

Table 5-1. QSF18 Recruitment Schedule

August		September		October		November		December	
1		1		1	Postcard mailing	1		1	
2		2		2		2		2	
3		3	Labor Day	3		3		3	
4		4		4		4		4	
5		5		5		5	Test – Day 1	5	
6	Begin dry run	6		6		6	Test – Day 2	6	
7	Reminder/non-	7		7		7	Test - Day 3	7	Final survey due.
8	DR Final survey	8		8		8	Test – Day 4	8	
9		9		9		9	Test – Day 5	9	
10		10		10		10	Test – Day 6	10	Prepare
11		11		11	2nd post card	11	Test – Day 7	11	Mail incentives
12		12		12		12	Test – Day 8	12	
13	DR data delivery	13		13		13	Test – Day 9	13	
14		14		14		14	Test - Day 10	14	
15		15		15		15		15	
16		16		16		16		16	
17		17	Print and stuff	17		17		17	
18		18		18		18		18	
19		19	1st mailing	19		19	Final survey	19	
20		20		20		20		20	
21		21	Post card printing	21		21		21	
22		22		22		22	Thanksgiving	22	
23		23		23		23		23	
24		24		24		24		24	
25		25		25	Last day of	25		25	
26		26		26		26		26	
27		27		27		27		27	
28		28		28		28		28	
29		29		29	Assign	29		29	
30	Purchase	30		30		30		30	
31				31	Text message test	31		31	

6. Survey Design/Methods (Subjective Design)

6.1 Research questions to be addressed

The QSF18 test is a practice session for the future LBFD community dose-response testing and this test plan covers activities aimed at refining future test protocols.

Both single event and daily cumulative noise levels and survey responses are being gathered, to provide a comprehensive dose response data set. The low boom noise from overland supersonic operations will affect a much larger percent of the population than the noise from the takeoff and landing operations at airports. The future LBFD community testing is aimed at providing answers to the following questions:

- At what single event and/or cumulative daily level (threshold) of low boom noise does a community become annoyed?
- What percentage of people are annoyed at a given level of low boom noise?
- What percentage of booms go unnoticed for a given noise level?
- How much does annoyance change with a change (either an increase or decrease) in the number of low boom noise events for the same cumulative level?
- What variation is observed in the annoyance response between and within individuals for the same cumulative level?
- How are categorical attributes such as vibration, rattle and startle related to the annoyance response?

The survey includes multiple geo-location methods including automated geo-location to analyze the annoyance response data at the time of the boom to estimate the noise dose. The responses to the survey questions will provide data to assist in interpreting the results of the dose-response models.

The primary objective of the research is to characterize the dose-response relationship governing the objective annoyance response to sonic thump sounds. Using the objective responses gathered in response to thumps presented, and accounting for demographic factors that may be associated with objective responses as measured in a background survey, in addition to factors about the thumps and geography that we can control and/or measure, we will model the annoyance primarily as a factor of the loudness of the thump sounds. In short, then, the primary research question will be: what is the magnitude of the parameter relating objective annoyance to subjective measurements of thump loudness?

6.2 Survey Implementation and confidentiality

Only PSU Survey Research Center researchers will have direct access to the participants' personally identifiable information and associated survey responses. All individuals who participate, will be assigned a unique identification number that will be associated with their survey responses. The participant's name, email, cell phone number and address will be used for test communications however it will not appear in the single event, daily summary or final feedback surveys. The participants will enter their unique code on project pages that correspond to their unique responses. This provides an extra layer of confidentially. The addresses provided will be used for determination of the noise dose. The contact information will be destroyed within a reasonable period after the completion of the field test. All personally identifiable information will be removed from the data and will only be linked by the unique ID. All subjective data sources will be merged into a single data set that will allow for detailed analysis.

The survey questionnaires will be formatted in a mobile enabled web platform, Qualtrics, a web based survey software tool. The src.survey.psu.edu page is a "hosting" page for information that includes the project information and the enrollment survey. Once the participant hits the enrollment button, they enter a Penn State enabled Qualtrics survey, a web enabled platform that is https. The respondent enters responses through the https Qualtrics survey platform.

Each respondent will be provided with a unique link. These unique links and invitations will be used as a way for matching subjects to responses. This unique link accesses the survey which can be completed multiple times. Each link will be associated with an access code (or "ID code") and the access code will be sent to each individual.

Participation reminders will be sent to all participants at the beginning and end of each day. Respondents will be informed to look for a text or an email, depending on their group assignment. Only the reminder group reminder group will receive reminders throughout the day.

The reminder group will be sent a reminder in the AM to participate, with the single event link. They will be sent texts throughout day reminding them to listen, with the link. Some of the texts will be sent just before a thump occurs and some will be random, with a maximum of 10 texts per day. They will be sent a text at end of day to remind them to complete the daily summary with the link.

The non-reminder group will be sent an email reminder in the AM to participate, with the single event link. They will not receive reminders throughout the day. They will be sent an email at the end of day to remind them to complete the daily summary with the link.

Implementing this code system performs a dual function. This system allows for the tracking of respondents, and it does not put any personally identifying information (such as name, email, etc.) into the shared data file. Only the respondent code is included with the response data. The surveys cannot be completed without the code.

The posttest feedback will work similarly, in that each person will be sent a code and a new "portal" page.

The Survey Research Center would generate an overview spreadsheet at the end of each day with columns associated with the respondents for that day. This overview would not contain all of the variables recorded from that day, but a select set of variables only for participants. The additional variables would include the geo-location, date and time of the sonic thump response and the single event annoyance rating. It is anticipated that respondents will periodically need to manually enter their locations. Delivery of daily survey summaries will be delayed by 1 day since they sometimes arrive the following morning. The daily summaries will include date, annoyance rating, and time of survey submission for all subjects.

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6.3 Parameters to be estimated and Analysis Model

The statistical analysis will evaluate the subjective response variables to identify relevant factors and correlate the subjective findings with the objective noise metrics. Noise measurements will be made in the surrounding community during the period of the survey administration. The analysis will utilize data dependent analysis options. The methods considered will be parametric, or non-parametric, based on the data gathered.

The analysis will focus on the following fundamental design concepts:

Single Event Analysis

This analysis allows for the assessment of subjective response as a function of noise level presented at different times throughout the test design. Comparisons can be made within responses from an individual participant (same person, different time, same/different levels), as well as between participants across the presentation variables (level, time of day). The single event analysis will afford a metric assessment that can be utilized in correlating human response to a single event certification metric, and to provide single event data for future consideration of community noise impact.

Cumulative Daily Analysis

This analysis affords the assessment of the participants rating of the overall day to correlate with the cumulative noise dose. The cumulative daily analysis assesses the current community noise impact metric, the Day Night Average Sound Level (DNL). DNL represents the accumulated noise level over 24 hours with a penalty of 10 dB given to operations taking place at night between 10pm and 7am. Comparisons can be made within responses from an individual participant as well as between participants across the presentation variables.

Development of a Dose-Response Model

An Exploratory Data Analysis (EDA) will be conducted prior to implementing the ANOVA or ANCOVA model to analyze the data. The EDA approach will be used to evaluate the appropriateness of including the multiple different covariates in the analysis, because a covariate should be included only if it has a significant relationship with the response. The EDA approach will investigate which variables explain a significant portion of the variability in the response. The main predictor variables will be the characteristics of the different noise environment (due to different geographic locations). The analysis will include as many interactions as appropriate dictated by the survey response data that is obtained.

The data will determine the components of the dose-response model of the annoyance. The annoyance response will be a function of non-noise co-variables, noise effects, and random effects, as outlined below. As noted inSection6.4, we plan to model the annoyance response as a function background survey demographics and factors about the thumps and geography (i.e. non-noise co-variables), primarily the measured noise effects, and random effects, as outlined below. The WSPRRR model will be of the form:

$Y = XB + B_M Met + ZA + E$, where:

Y is an nx1 vector containing all of the *annoyance responses* measured from all participants across all units of study to be modeled. We model the annoyance as a function of:

Non-noise covariates:

- X is an nxp matrix of covariates that interact with the annoyance response.
  - These are primarily measured via the background survey.
  - These can include things such as family composition (presence of young children), general sensitivity to neighborhood noises, etc.
- B is a px1 vector of coefficients to be estimated. These parameters govern how much these demographic factors can account for annoyance responses, and help to sharpen the understanding of the relationship of the loudness to the annoyance by accounting for additional terms that might also impact the relationship.

Noise effects:

- B_M is a coefficient indicating the effect of the objective measure of noise. This parameter is the primary target. Estimating the magnitude of this parameter addresses the main research question.
- Met is an nx1 vector of the objective measures of noise.

Random effects:

- Z is a nxk matrix of random effects (e.g. community, day of response, respondent ID)
- A is a kx1 vector of random variables
- E is a nx1 vector of estimation errors
  - Each random effect is a source of variability in the data, and as random variables they all have variance parameters associated with them. While these are parameters to be estimated and are useful in creating more powerful tests of hypotheses, they are rarely explicitly discussed/analyzed.

As noted above, Y is the annoyance response measured from all participants across all units of study to be modeled; this can include either single events or daily summary responses, and that unit of study will dictate which random effects are included. We will always be able to include respondent ID and day as random effects, but if we model single events, we can also include a thump ID to incorporate correlation of responses for a specific event. The predictive models can be linear or nonlinear based on the data obtained; while the formulation is that of a standard linear model, transformation of the data can induce underlying nonlinearity, as can inclusion of interaction terms and transformation of variables (polynomial, trigonometric, etc.). The analysis of the annoyance response will encompass the full range of annoyance response ratings as well as the % Highly Annoyed.

6.4 Estimation Procedures

As outlined in Section 6.3 above, the general framework for the model is a mixed effects ANCOVA. This model will incorporate either a repeated measures (daily summary) or doubly repeated measures (single event) framework to help account for the complex layers of correlation in the data. In addition to modeling the correlation between responses from the same individuals, we will also allow flexibility to account for various other sources of correlation via the remaining random effects that can, for instance, allow all subjective ratings of a common event to be correlated if some common characteristics of the event (timing, meteorological conditions, etc.) make those ratings more consistent with one another than would be expected. This model will be fit using the statistical software SAS Studio 3.6 (SAS Institute, Cary NC), most likely utilizing the PROC MIXED procedure for fitting mixed effects linear models.

As an example of the type of model we could run and associated output we might see, the following simplified analysis was conducted for some data acquired as part of the WSPR 2011 study. In this study, we only have a single community of respondents, and while a background survey was conducted and we have a full suite of non-noise covariates to consider, for the sake of simplicity only a single covariate (response mode: paper, non-mobile web, Apple iPad) is included in the model. An objective measure of noise is included, and this can obviously be replaced by any metric of interest. Finally, two different random effects are included; we include the day of the event to account for similarities amongst all responses recorded on the same day, and we include respondent ID to account for similarities amongst all responses recorded by the same respondent. The resultant output from SAS PROC MIXED is shown in Table 6-1, edited for brevity.

In particular, the final two tables of Table 6-1 are of the most interest. In the next to last table, we actually obtain estimates of the various elements of the px1 vector of parameters governing how the annoyance responses are related to the non-noise covariates and the metric (row named MET). In the final table, overall tests are conducted for the statistical significance of these estimates; that is, we see here if our estimates should allow us to conclude whether or not the observed relationships are indicative of true relationships in the population of all respondents. So here, for example, we should believe there is a real relationship between the annoyance and the metric ($p<.001$), but we should not believe that the mode by which response were recorded was related in any way to the average annoyance response (because $p=.486 > .05$).

Table 6-1. Example modeling output from SAS PROC MIXED (edited for brevity)

Model Information	
Data Set	MYLIB.DAT
Dependent Variable	annoy
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information	Levels	Values
mode	3	Apple Paper Web
s_day	10	4 7 8 9 10 14 15 16 17 18
id	52	2312 2326 2331 2333 2340 …

Dimensions	
Covariance Parameters	3
Columns in X	5
Columns in Z	62

Covariance Parameter Estimates	Estimate
s_day	0.1626
id	4.4929
Residual	2.4187

Solution for Fixed Effects						
Effect	**mode**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**
Intercept		-5.1740	0.5641	9	-9.17	<.0001
MET		0.08101	0.003651	2307	22.19	<.0001
mode	Apple	0.5492	0.7354	2307	0.75	0.4552
mode	Paper	0.8206	0.7069	2307	1.16	0.2459
mode	Web	0	.	.	.	.

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
MET	1	2307	492.35	<.0001
mode	2	2307	0.72	0.4860

7. Sonic Boom Analysis for Test Dose-Design

Analysis of the sonic boom dive maneuver is required for several aspects of this test design. An examination of the footprints for the selected Galveston area was conducted to understand potential footprint variability. Subsequent analysis can provide possible levels at particular locations in the test area for different dive waypoint locations. These analyses also feed into the design of the noise dose itself. These aspects are described in this chapter.

7.1 Process for determining metrics at participant locations

In order to maximize regulatory confidence in the dose-response data from the future LBFD community tests, it is important to preserve the link to empirical data for the sonic boom exposure levels. When study participants are near a monitoring station, the sound level recorded at that particular station can be used as an accurate indicator of the level experienced by the participant. While one could use the closest monitor measured values to obtain the participant exposure, this can introduce errors due to metric gradients inherent across the study area. Given the inevitable participant mobility during the course of the data gathering periods it is prudent to improve the dose calculation by accounting for sonic boom exposure gradients across the footprint. The methodology described below is also proposed for use with the future LBFD test. One important differentiation between the expected footprint shapes and gradients is due to the differences in the employed flight procedures. The Galveston test will utilize a low-boom dive maneuver which results in a crescent shaped footprint with complex metric gradients and somewhat complicated exposure metric calculations, whereas the future LBFD test will rely on steady speed constant altitude overflights and a rectangular footprint with significantly lower metric gradients and simpler metric calculations. To the greatest extent possible, the methodology to be utilized for the Galveston test will mirror the planned methodology for the future LBFD tests. Complexity is added to the process to provide reasonable dose estimates in order to facilitate statistical dose-response analysis so that risk reduction objectives can be met. We have identified in the process below, instances where revisions to the interpolation process is necessitated to accommodate the low-boom dive testing protocol to be employed in Galveston.

Empirical metrics provide the best measure of the sonic boom at deployment locations, but previous tests with traditional N-wave booms have shown that levels can vary substantially over short distances especially due to turbulence (Maglieri *et al.*, 2014). Interpolation of measured levels will be used to estimate metrics at participant locations, with the empirical metric interpolation process guided in part by predicted metrics from PCBoom analyses. Measured test-day meteorological data profiles and as-flown trajectories and aircraft weights will be used in PCBoom to model test-day footprints.

The basic process for metric interpolation is as follows. The metrics at monitor locations will be computed from measured signatures, and participant locations at time of boom will be used to set interrogation points. Participant locations suitably close to monitors will be associated with measured levels at those monitors, while metrics at other locations will be determined via interpolation and extrapolation of measured metrics.[1] As-flown trajectory data and measured test-day weather will be used in PCBoom to model a finely-resolved footprint using computationally fast Taylor shock approximation (standard PCBoom). The monitor and participant locations will be used with this PCBoom footprint to construct a coarse grid of points to be examined using a higher fidelity Burgers equation solver (PCBurg), which models molecular relaxation in propagating rays from the aircraft to the ground. The PCBoom grid will be used to determine the origin of rays impinging on the ground near these points, and PCBurg will be run for each of these rays to create a coarse grid of metrics modeled using PCBurg. PCBurg is needed to capture the effects of molecular relaxation which is critical for modeling of loudness metrics such as PLdB. This process is illustrated in the flowchart shown in Figure 7-1. Comparisons of predicted and measured PLdB values are also shown.

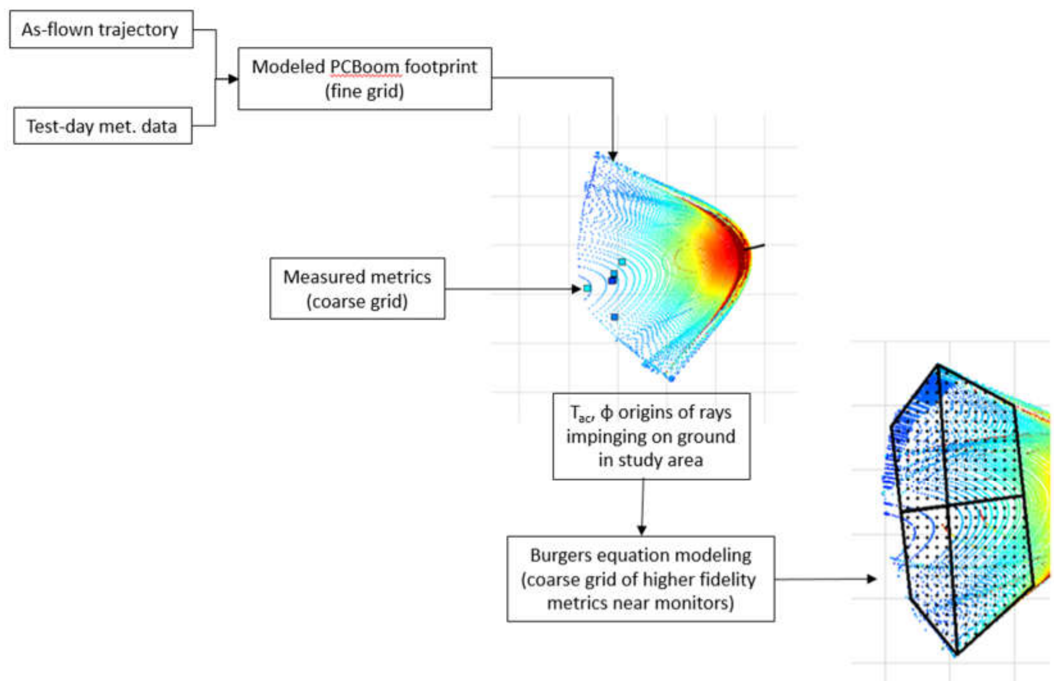

Figure 7-1. Flowchart for predicting metrics to guide interpolation of measured metrics

[1] After the test has been conducted, an uncertainty analysis can be performed to quantify the metric certainty (in dB) as a function of distance/location in the footprint. We envision the uncertainty quantification to be based on down track location and distance from the crescent edge with down track location being the dominant factor.

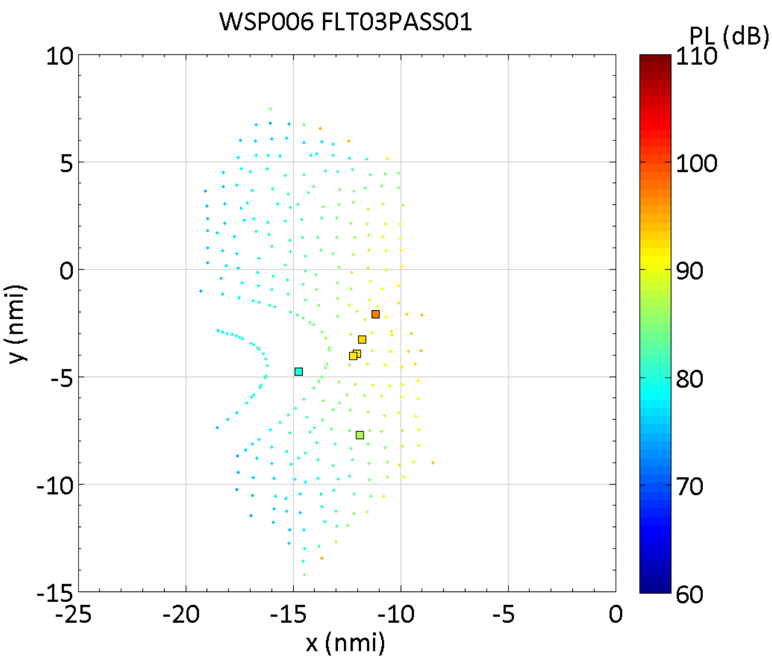

Figure 7-2. Comparison of measured metrics with coarse Burgers mesh for AFRC 2017 flight test. Large points are monitor and measure metrics, smaller points represent levels from a coarse PCBurg mesh.

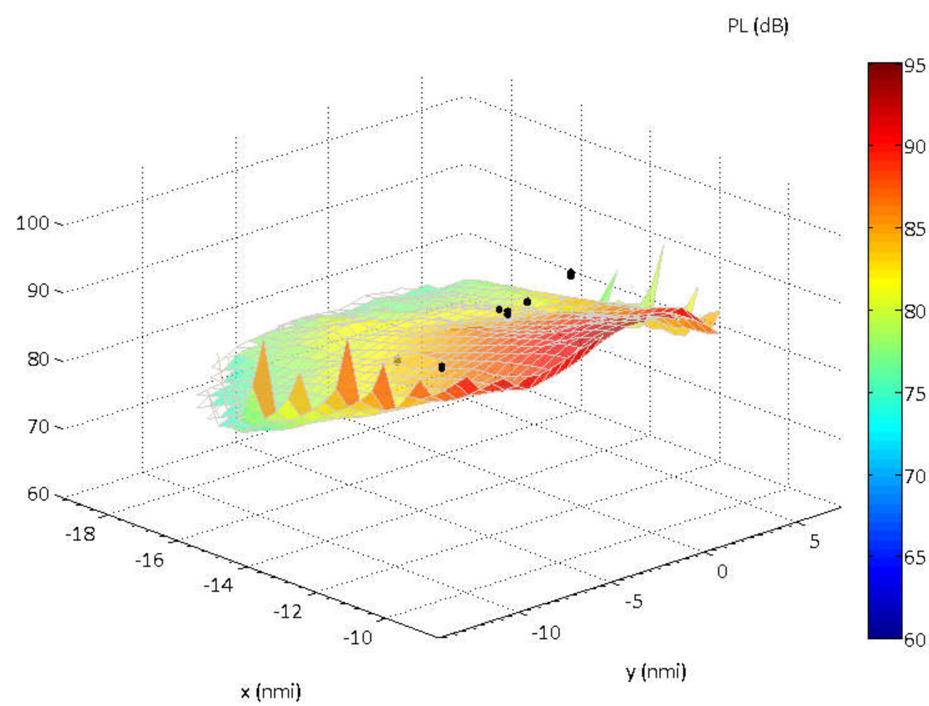

Figure 7-3. PLdB surface prediction, with measured levels as black points

Interpolation of measured metrics will be done using standard 2D interpolation techniques, e.g. bilinear or bicubic interpolation. Measured levels represent the most accurate indication of metrics, but may be too sparse to capture the shape of spatial variations in sound levels. Comparison of the Burgers mesh with measured metrics, shown in Figure 7-2. will be used to guide the selection of an appropriate interpolation scheme and depending on the local distribution of monitors and participants may be used to calculate offsets. In the simplest scheme, the Burgers mesh provides a direct offset from measured metrics. For example, if a monitor at location 1 measures L_{1meas} while a participant is at location 2, and PCBurg is used to model levels L_{1mod} and L_{2mod} at each of these locations, and then the level at participant location L_2 can be estimated as $L_2 = L_{1meas} + L_{2mod} – L_{1mod}$.

The process illustrated above describes a single value point estimate of the level. This is included as an illustration of a simple method for estimating levels at participant locations and will be used together with a higher-order method similar to the one described, in which a weighted average of nearby monitors is computed, using distance as a weighting factor. Estimated levels from these methods will be compared with interpolated values using the predicted levels to guide the shape/order of interpolation scheme. The ultimate decision on the method chosen will depend in part on the acquired data from the test itself.

Regarding dose uncertainty by comparing single event dose response curves using these three methods, dose based on predictions and measurements, and interpolated metrics only would make a valid comparison. Doses based on predictions only should be coupled with an estimate of the uncertainty, which is most readily determined by comparison with measurements.

The interpolation/extrapolation scheme will be one in which a surface is fitted to the measured data based on the characteristics of a predicted surface. The PLdB surface predicted in the Figure 7-3 suggests that linear interpolation in the trackwise distance is appropriate for the low pressure portion of the footprint, and that a higher-order polynomial of even degree such as parabola or a fourth-order polynomial would capture the major features in the lateral direction. The spikes at the edges of the footprint are due to focal regions and would not be included as part of surface fitting. Thus, the distribution of measured levels together with metric surface predictions made using as-flown trajectory data and measured meteorological data will be combined to form a metric surface anchored by measured data points. To determine interpolation accuracy, measured levels will be used to test the interpolation scheme by removing a measured level from the dataset and then using the interpolation methods to estimate the level at that location.

For some instances the respondent location and the noise monitors will be outside of the footprint predicted by ray theory. The noise dose for participants will be based on an interpolation across empirical measurements. The PCBoom predictions are used to update the interpolation. For locations outside the predicted footprint area, the purely empirical interpolation method will be used.

The exact procedure for determining metrics at participant locations will continue to be refined as the actual order of fitting surfaces may change with day-to-day boom variations. This is an example of a complex procedure that is expected to be more straightforward for LBFD test. The extent to which 2D spatial gradients are present in low-boom dive footprints is likely greater than LBFD footprints, which may be essentially one dimensional for steady level flight. As such, simpler models could potentially be used to interpolate/extrapolate metrics in LBFD tests.

Additionally, comparison of measured and modeled signatures as shown in Figure 7-4. indicates that it may be necessary to account for propagation through atmospheric turbulence in the modeled signatures to accurately compute metrics. Because best practices for turbulence modeling are presently dynamic, incorporation of updated methods to the prediction process will continue as those developments become available.

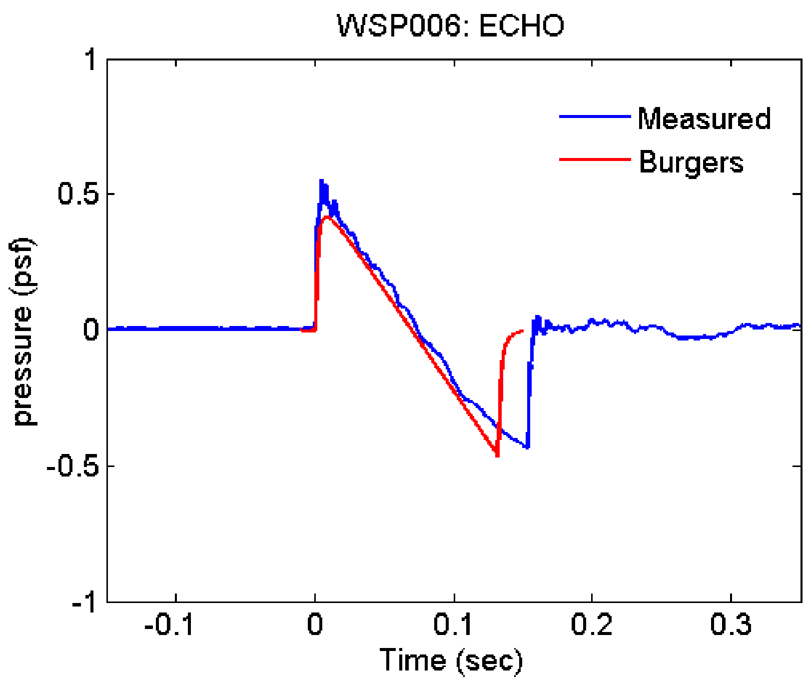

Figure 7-4. Comparison of measured and modeled ground signatures for AFRC 2017 pre-test

Propagation through atmospheric turbulence affects ground signatures and metrics. Filters currently implemented in PCBoom to model these effects as an envelope of potential ground waveforms for Nwave signatures, are based on empirical measurements. Using the PCBoom- filters will transform a given metric result to a range of results which can be considered in the statistical dose-response modeling.[2] Because real atmospheric turbulence varies both spatially and temporally, those filters can vary in applicability and accuracy. Measured ground signatures obtained during the Galveston tests will be used to improve fidelity of PCBoom predictions by supplying local indications of test-day turbulence effects on incident rays and subsequently inferring positionally dependent metrics. A range of measured meteorological parameters will be used to set stochastic perturbations in the modeled signatures based on the observed measured signatures. This modeling procedure will be used to develop a turbulence overlay and refine the interpolation process for obtaining metric values at participant locations.

[2] Turbulence FIR filters developed at PSU are implemented in the WCON module of PCBoom, and thus these filters ae not currently available as part of the Burgers solver. The only loudness metrics in WCON are based on a simple shock thickening relation implemented in PCBFoot. PCBoom code modifications will need to be made to apply the turbulence FIR filters to resultant PCBurg ground solutions. It is also feasible that new methods resulting from the SonicBAT program could be used when they become available.

7.2 PCBoom Footprint Calculations

Predictions of the size and shape of a typical low-boom dive footprint are made using PCBoom. Trajectory data describing an as-flown low-boom dive maneuver from the NASA Sonic Booms on Big Structures (SonicBOBS) project is used as a template for PCBoom modeling. The trajectory is re-vectored such that it is approximately perpendicular to the Galveston Island coastline, and translated to place the high-pressure portions of the footprint offshore. Meteorological conditions have a large influence on the shape of the footprint, and as part of the site selection process, a study of weather effects was undertaken. Historical weather balloon data measured between 2006 – 2016 in the months of August through November were used in this meteorological study. Specifically, weather data from station CRP measured at 00 Zulu and 12 Zulu on every 5th day were extracted and used to model footprints in PCBoom[3]. The resulting collection of approximately 600 footprints was then used in a geographic cell-based analysis. The collection of footprints was overlaid on a grid of square cells with dimension 2000 ft., and the maximum value of all PCBoom points in each cell was recorded for each footprint.

Atypical weather conditions can change the size and shape of a boom footprint such that the far down-track regions may be outside the footprint on most days. One goal of the meteorological analysis was to determine a region that is likely to coincide with a modeled footprint for a majority of historical weather profiles. The mean pressures for each cell were used to fill in a mean boom footprint. Cells that recorded an overpressure higher than 0.75 psf for more than 50% of cases were marked as high-pressure cells to be placed offshore. Similarly, cells that recorded non-zero overpressures in less than 60% of cases were marked as low probability cells to be excluded from recruitment areas. The remaining region of the mean footprint was divided into four quadrants. The mean footprint shown in Figure 7-5 has the high-pressure regions and low probability regions greyed out. Several probability levels were considered as criteria for quantifying meteorological effects on footprint shape and size, and 60% was determined by inspection to balance low-pressure footprint area with exclusion of cases with atypical small or large footprints.

[3] The PCBoom meteorological analysis conducted was based on the empirical weather archive used for the original site selection analysis which led to selection of the Galveston test site. The map at the University of Wyoming historical meteorological website illustrates stations for which data are available, and one can see that CRP and LCH (Lake Charles, LA) are the closest stations to Galveston. PCBoom was set up to accommodate the native data format from this archive which is why it was selected. http://weather.uwyo.edu/upperair/sounding.html

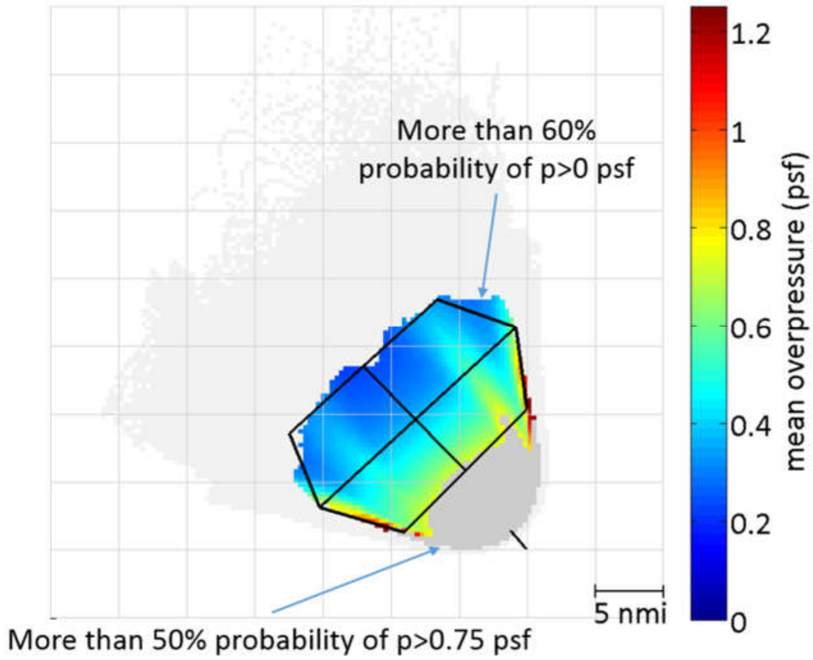

Figure 7-5. Mean footprint from meteorological analysis

The position of the footprint relative to the coastline was shifted based on four scenarios, illustrated in Figure 7-6. , Figure 7-7. , Figure 7-8. , and Figure 7-9. This was modeled in PCBoom by changing the coordinates of the trajectory origin. The same template dive trajectory was used in all four cases. For dive waypoint 1 (Figure 7-6), the mean footprint is placed to maximize the on-shore portion while keeping high-pressure cells off shore. Dive waypoints 2 (Figure 7-7), 3 (Figure 7-8), and 4 (Figure 7-9) were set to shift the footprint approximately 5 nmi, 7.5 nmi, and 9.8 nmi respectively in the offshore direction, to lower the statistical overpressure values at fixed locations. Using dive waypoints 3 and 4, the majority of the usable portion of the footprint is offshore, and only Galveston Island falls within the 60% boom criterion region. It is worth noting that depending on daily weather, regions northwest of mean footprints may also experience booms though they are expected to be very low level.

This approach to providing variation for the design of the subject low-boom dose is necessary given the underlying shape of the low-boom dive footprints. Given the constraints that high-pressure and focal areas must be kept offshore, and that the trackwise extent of the footprint is limited by dive altitude envelope, translating dive waypoints to shift the footprint relative to fixed locations is the only feasible way in which levels can be varied at specific locations. This introduces complexity, in that setting a low level near the shore effectively moves inland participants outside the effective boom footprint.

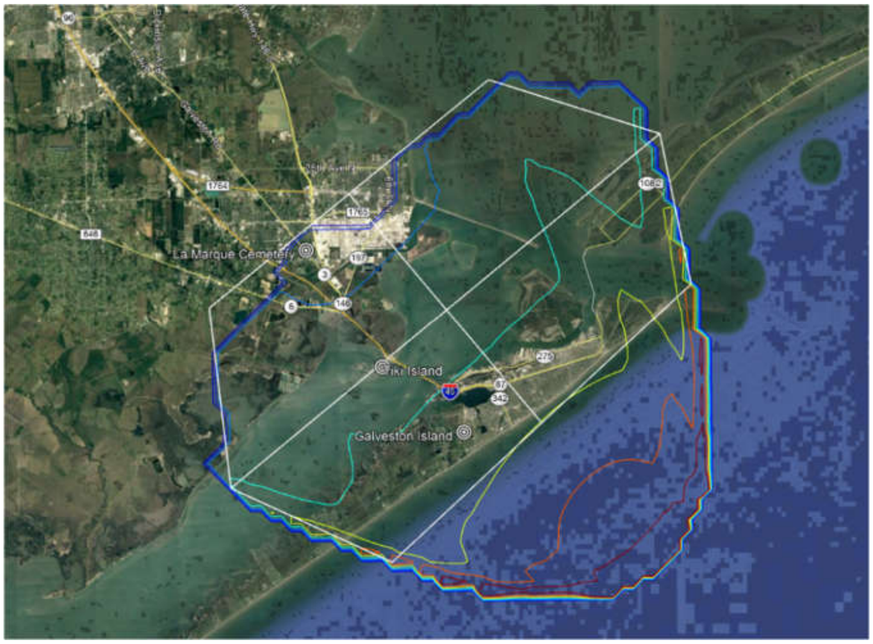

Figure 7-6. Mean footprint placement using dive waypoint 1

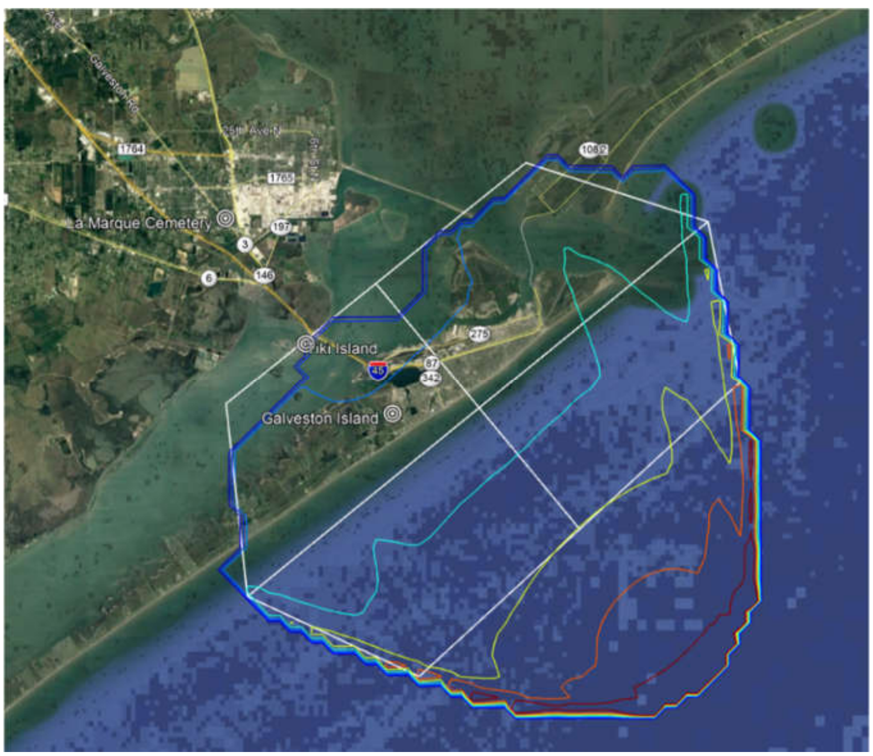

Figure 7-7. Mean footprint using dive waypoint 2

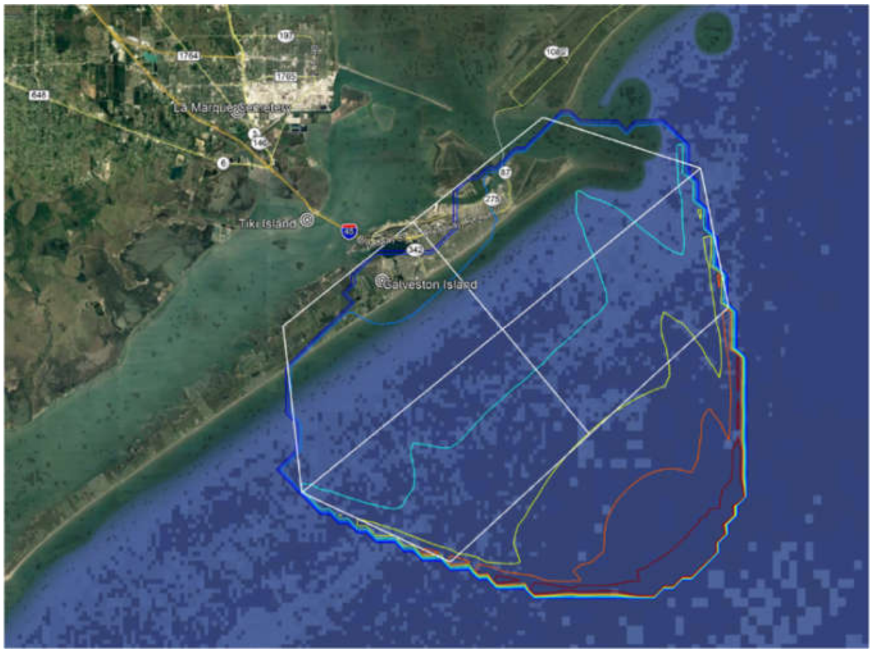

Figure 7-8. Mean footprint using dive waypoint 3

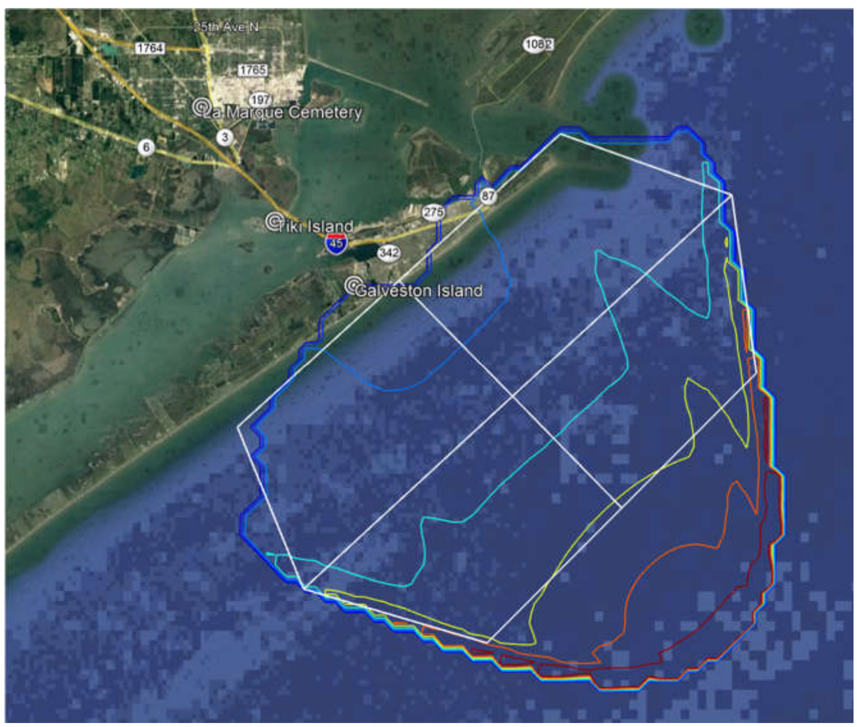

Figure 7-9 Mean footprint using dive waypoint 4

7.3 Estimating loudness metrics for noise dose design

As part of the noise dose design, loudness metrics were modeled using PCBoom / PCBurg at three candidate sites: Galveston Island airport, Tiki Island, and La Marque cemetery. These sites represent three different down-track distances. The sites are indicated by black arrows in Figure 7-10 and their coordinates are in Table 7-1 .

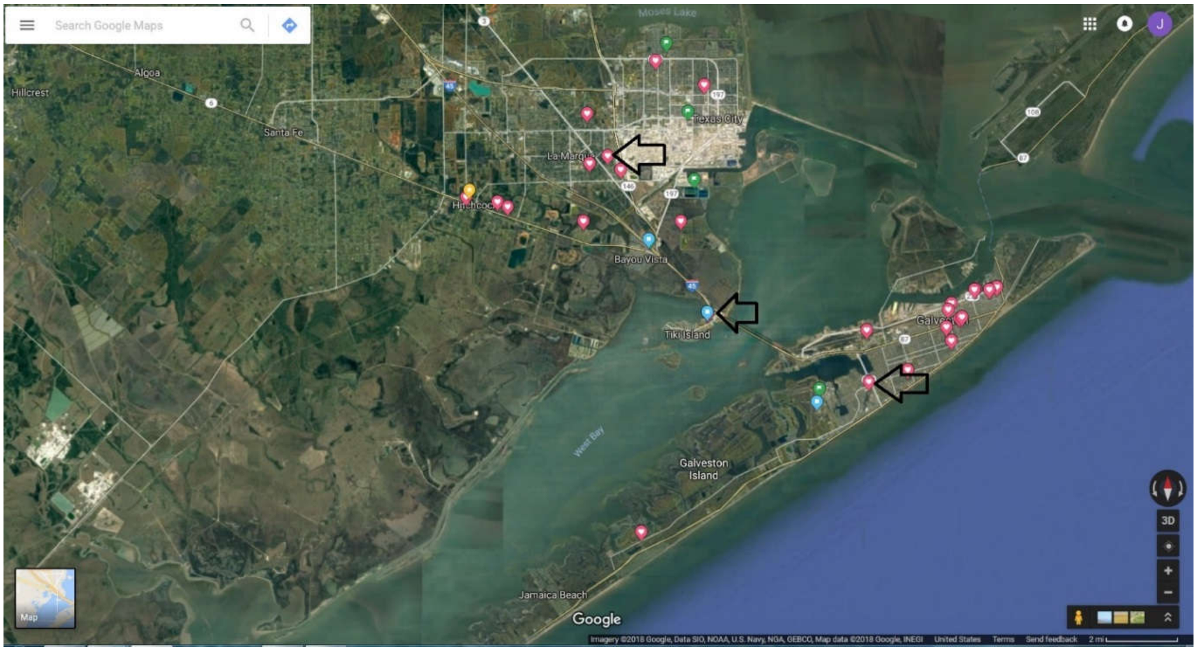

Figure 7-10. Candidate sites used for noise dose design

Table 7-1 Candidate site for noise dose design

Site number	Site name	Latitude	Longitude
1	Galveston Island @ Airport	29.263121	-94.856428
2	Tiki Island	29.299023	-94.907254
3	La Marque Cemetery	29.363193	-94.954457

The footprint predictions illustrated in the previous section are statistical averages of footprints modeled using a collection of historical weather data. To model loudness metrics at specific sites, a single case is modeled in PCBoom and selected rays corresponding to the site locations are used to start PCBurg calculations. A weather profile was chosen such that the modeled footprint had overpressure levels similar to the mean footprint at the candidate sites. PCBurg cases were then run to estimate PL at those sites as shown in Figure 7-10 for four template dive locations. For dive waypoints 2 through 4, shifting the footprint offshore caused location 3 and then location 2 to fall outside the PCBoom footprint prediction, so PCBurg cases could not be run.

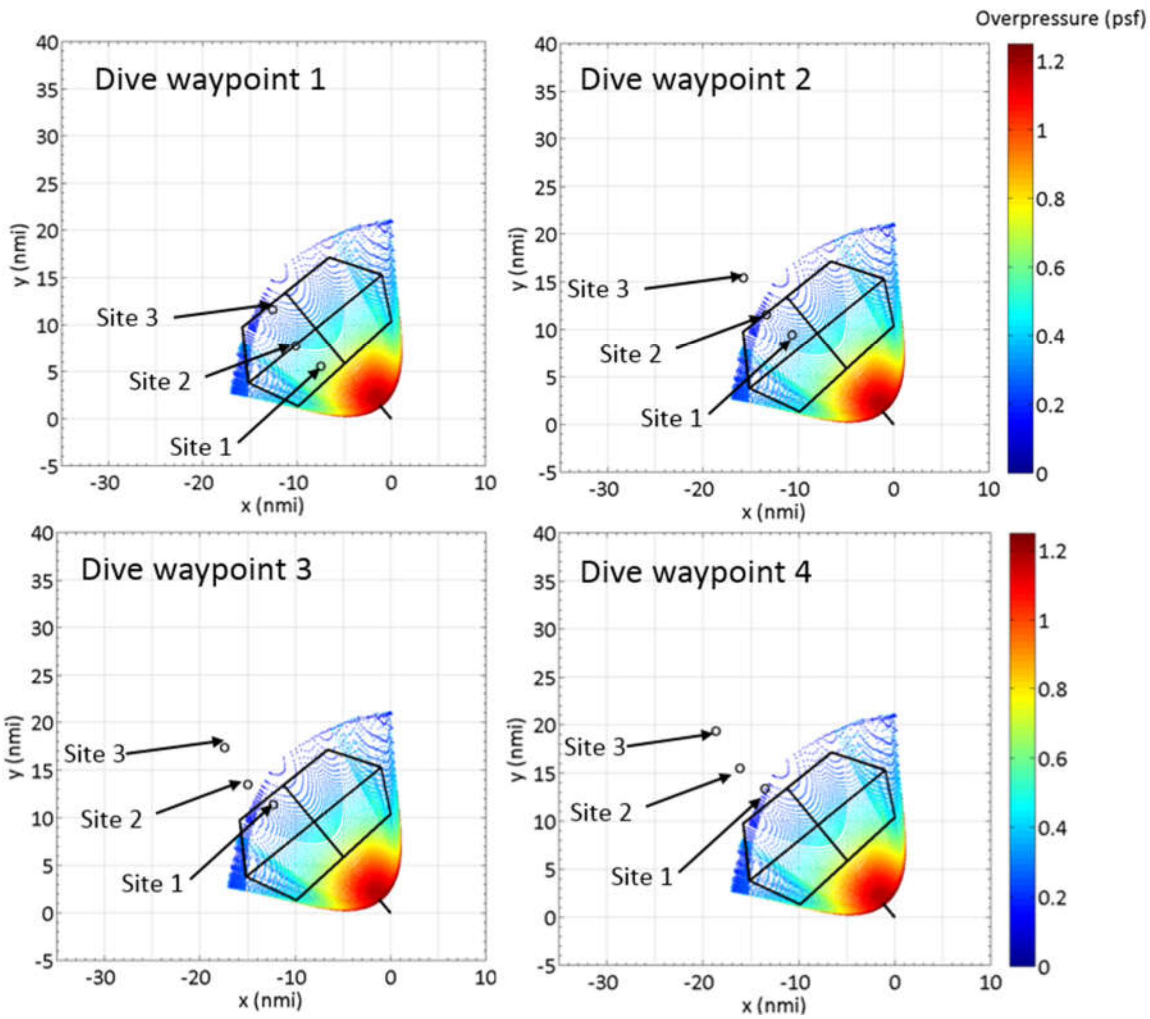

Figure 7-11 Footprint predictions for dive waypoint 1-4

The template footprint for the four dive waypoints is illustrated in Figure 7-11, together with the relative locations of the candidate sites. The corresponding maximum overpressures and PL levels for each dive waypoint are given in Table 7-2, Table 7-3, Table 7-4, and Table 7-5.

Table 7-2 Predicted loudness metrics for dive waypoint 1

Site number	PL (dB)	Pmin (psf)	Pmax (psf)
1	93.3	-0.57	0.53
2	87.5	-0.37	0.35
3	78.0	-0.19	0.18

Table 7-3 Predicted loudness metrics for dive waypoint 2

Site number	PL (dB)	Pmin (psf)	Pmax (psf)
1	84.0	-0.30	0.28
2	76.4	-0.17	0.16
3	-	-	-

Table 7-4 Predicted loudness metrics for dive waypoint 3

Site number	PL (dB)	Pmin (psf)	Pmax (psf)
1	79.7	-0.22	0.20
2	-	-	-
3	-	-	-

Table 7-5 Predicted loudness metrics for dive waypoint 4

Site number	PL (dB)	Pmin (psf)	Pmax (psf)
1	73.7	-0.14	0.13
2	-	-	-
3	-	-	-

8. Noise Dose Design (Objective Design)

8.1 Design Overview

The WSPRRR noise dose design parallels the design that was implemented for the WSPR test effort. It consists of a range of boom levels. The final noise exposure design balances CDNL exposure across test days, as well as balancing the number low, medium, and high booms across the design. The experimental design was developed with the cumulative daily noise exposure as the primary controlling variable. The daily noise exposure summarizes the single event exposures for that day. The goal was to identify a range of daily exposures and replicate them within the design.

8.2 Noise Design

This noise dose design includes an "If-Then" noise dose increment implemented during the field test and based on monitoring a summary of the annoyance response to noise exposure in the community across the time of the field test. The annoyance summary will be monitored daily during the field implementation of the noise design.

For event days 1 to 3, the noise dose exposure is designed not to exceed 80 PLdB per event. If the summary results indicate the community is not excessively annoyed at these levels, the noise plan exposure for days 4 to 5 will be increased and the exposure will not exceed 85 PLdB per event for days. Across each of these days there will be a distribution of sonic thumps at lower levels as well.

For days 6 to 7, the noise plan exposure will be designed not to exceed 90 PLdB per event. The design will continue to include sonic thumps at lower levels. If the overview summary of survey responses indicate the community is not highly annoyed, the noise dose design will be incremented for the last days of the test.

For day 8, the noise plan exposure will be designed not to exceed 95 PLdB per event. Sonic thumps at lower levels will be included as well.

The noise plan includes eight flight days over a 10 day period distributed over two weeks. The flight test will be conducted between 7 AM and 5 PM. The first flight of each day takes off at 8 AM and the last flight takes off at 4 PM to fit within the 7 AM to 5 PM flight test period. There will be two to three F-18 flights per day for eight test days. The planned time periods will be distributed throughout the day and over the test period. The 10 test days are distributed over a two week period to allow for weather make up days. The plan can accommodate the potential for a maximum of six 10 hour days followed by a respite day that provides a break for the flight crew over the course of the two-week test period. The boom order and the boom spacing may also be changed on a daily basis due to operational and environmental considerations.

8.3 Representative Noise Dose Design

The dose response design will present a range of low boom levels that will be evaluated with respect to the subjective response obtained from survey participants. The development of the noise dose is based on loudness metrics that were modeled using PCBoom / PCBurg at three candidate noise monitor sites: Site A: Galveston Island airport, Site B: Tiki Island, and Site C: La Marque cemetery (furthest inland). These sites correspond to three different down track distances and represent a focal point for three distinct noise impact communities based on selected Galveston atmosphere. (See Section 7.2). The metrics were computed for template November weather case using Burgers equation propagation and provided the basis for the calculation of the daily noise dose based on the number of events. Four dive waypoints were identified. Dive point 1: maximizes the on-shore area for the noise impact. Utilization of Dive 1 creates High (H) level booms at the Galveston location, with reduced noise impact at the other two community locations due to the increased distance from the dive point. Dive 2 is shifted 5 nmi offshore and creates Medium (M) level booms at the Galveston location, with reduced noise impact at Tiki Island. The use of Dive 2 is sufficiently off shore that the La Marque cemetery is no longer under the boom carpet for Med level booms. Dive 3 is shifted 7.5 nmi offshore and creates Low (L) level booms at the Galveston location. This dive point is sufficiently off shore that both Tiki Island and La Marque are no longer under the boom carpet. Dive point 4 footprint is shifted approximately 9.9 nmi from dive waypoint 1and is placed with Galveston island at the downtrack edge. It creates quiet level booms at the Galveston location but is sufficiently off shore that both Tiki Island and La Marque are no longer under the boom carpet. As such, these locations do not receive Quiet and Lo level booms from the further dive points, however they may still experience some rumbling noise. Participants in these areas, and outside the planned footprint may experience low boom noise and the levels at the outer edge of the footprint may be even lower than planned. At present we don’t have an analytical means to show any predicted levels, but empirical data will be gathered and analyzed where possible.

The uncertainty associated with the assigned PLdB metric value for these three locations for the three different dive locations is currently under investigation. Future updates to the loudness level might change the individual PLdB values, however it is not expected to appreciably impact the overall noise exposure design in terms of the flight schedule and identified dive locations.

The noise metrics implemented include PL, CSEL and ASEL with values provided for Lo, Med and Hi single event levels that correspond with the different dive points. The Quiet, Lo, Med and Hi, PL dB levels at Galveston are 73.7, 79.7, 84.0 and 93.3 respectively. Sample cumulative metric calculation tables follow for each site location, showing the calculation of PLDN, CDNL and DNL. The maximum psf associated with each single event level is presented in the tables as well. The targeted levels of 0.13, 0.2, 0.28, 0.53 psf correspond to the Quiet, Lo, Med and Hi single boom levels at Galveston. It should be noted that the psf levels are reduced at the locations further inland. For instance, a M (.28 psf) at Galveston has a noise impact at Tiki Island of .16 psf, which approximates a Quiet (.13 psf) on Galveston. Each time a M is heard at Galveston the residents on Tiki Island will hear a Quiet level boom, based on Galveston definition of noise impact levels. The noise dose per day was based on the cumulative daily noise exposure response as represented by the daily DNL, PLDN and CDNL. These measures provided the primary comparison between experimental test days in the field. Table 8-1, Table 8-2 and Table 8-3 contain an example calculation cumulative dose metrics for 1Q, 3L, 2M and 3H boom levels for Galveston, Tiki Island and LaMarque Cemetary respectively.

Table 8-1 Calculation of Cumulative Metric Values Site 1 Galveston

NASA LBFD Undertrack Metric Values					
*Note: Cumulative Metric Value: No Evening / Night Time Penalty					
Site A: Galveston	PL	CSEL	ASEL	Max Psf	Enter Number of Events
Dive 4 Quieter	73.70	84.10	60.30	0.13	1.00
Dive 3 Lo	79.70	88.40	65.80	0.20	3.00
Dive 2 Med	84.00	91.20	69.90	0.28	2.00
Dive 1 Hi	93.30	97.30	79.30	0.53	3.00
Cum.Metric Value	49.19	53.84	35.18		
	PLDN	CDNL	DNL		
	DNL(PL)				

Table 8-2 Calculation of Cumulative Metric Values Site 2 Tiki Island

NASA LBFD Undertrack Metric Values					
*Note: Cumulative Metric Value: No Evening / Night Time Penalty					
Site B: Tiki Island	PL	CSEL	ASEL	Max Psf	Enter Number of Events
Dive 4 Quieter	0	0	0	0	1
Dive 3 Lo	0	0	0	0	3
Dive 2 Med	76.4	86.0	62.6	0.16	2
Dive 1 Hi	87.5	93.4	73.2	0.35	3
Cum.Metric Value	43.09	49.27			
	PLDN	CDNL	DNL		
	DNL(PL)				

Table 8-3 Calculation of Cumulative Metric Values Site 3 La Marque Cemetery

NASA LBFD Undertrack Metric Values					
*Note: Cumulative Metric Value: No Evening / Night Time Penalty					
Site C: La Marque Cemetery	PL	CSEL	ASEL	Max Psf	Enter Number of Events
Dive 4 Quieter	0	0	0	0	1
Dive 3 Lo	0	0	0	0	3
Dive 2 Med	0	0	0	0	2
Dive 1 Hi	78.0	87.2	64.1	0.18	3
Cum.Metric Value	33.37	42.57	19.47		
	PLDN	CDNL	DNL		
	DNL(PL)				

8.4 Range of Single Event Dose Levels

Various combinations of Q, L, M and H single event booms were calculated to assess the associated cumulative metric values. These values were used to identify daily CDNL ratings that could be used for the daily noise dose. Samples of those calculations are presented in Table 8-4.

Table 8-4 Comparison of cumulative metric values from single event combinations at Galveston

Levels	1Q	4Q	2Q, 2L	3Q, 1L	6Q	4Q,1L	4Q,2L	3Q,2L,1M
DNL(PL)	24.3	30.32	34.28	32.74	32.08	33.32	35.08	37.66
CDNL	34.7	40.72	43.38	42.25	42.48	42.96	44.42	46.01
DNL	10.9	16.92	20.49	19.06	18.68	19.68	21.35	23.74
Levels	4Q, 3L	2Q,3L,1M	2Q, 1L,1M	2Q,2L, 2M	1Q,4L, 1M	2Q,1L,3M	3L,2M	2Q, 3L,2M
DNL(PL)	36.33	38.22	36.53	39.27	38.72	40.11	39.53	39.79
CDNL	45.52	46.52	44.62	47.17	46.98	47.73	47.33	47.78
DNL	22.56	24.28	22.56	25.27	24.76	26.07	25.51	25.80
Levels	6L	2Q,2L, 3M	1Q,2L,4M	7M	1L,2M,1H	2Q, 1L,3M,1H	2L,4M	2Q,2L,2M,2H
DNL(PL)	38.08	40.54	41.45	43.05	44.97	45.42	41.36	47.60
CDNL	46.78	48.27	49.00	50.25	49.99	50.82	48.83	52.44
DNL	24.18	26.52	27.39	28.95	30.95	31.41	27.29	33.60
Levels	2Q,4M,2H	2L,2M,3H	3L,2M,3H	1Q,1L,1M, 3H	1Q,1L,2M, 3H	1Q,1M, 4H	2L,6H	2M,6H
DNL(PL)	47.87	49.11	49.17	48.91	49.07	50.06	51.74	51.85
CDNL	52.78	53.64	53.79	53.24	53.54	54.23	55.86	56.02
DNL	33.85	35.11	35.17	34.91	35.07	36.06	37.75	37.84

The daily noise dose is the cumulative amount of sonic boom noise that the respondent is exposed to each day. Various combinations of number of events for Q, L, M and H impact were calculated using the Galveston Cumulative Metrics. Noise dose combinations were identified that spanned the potential range for the daily noise dose. This range was broken into subsets that were defined by CDNL ranging from 40 to 58 and by adjective descriptors from quietest (yellow) to loud (red) as presented in Table 8-5.

Table 8-5 Potential range of Daily Noise Dose

QSF 2018 Planning		
Perception	**CDNL**	**Range**
Quietest	**39.9 - 43.9**	**4.0**
Quiet	**44 -47.9**	**4.0**
Moderate	**48 - 50.9**	**3.0**
Mod. Loud	**51-53.9**	**3.0**
Loud	**54-57.5**	**3.5**

From the set of potential noise dose combinations a subset at site A was identified for consideration in the noise dose design. A similar set of doses were also calculated at sites B and C. These combinations were then compared across the three communities using CDNL. They are presented in Table 8-6 for Site A, Galveston and span the full potential noise dose range. The comparisons of CDNL for various combinations across the three sites are presented in Table 8-7.

From that subset of potential cumulative noise doses, an attempt was made to identify combinations that resulted in similar impact across locations. At site A, multiple combinations were observed that resulted in a CDNL of ~42, ~47 and ~52. Modifications of these combinations were attempted to identify additional combinations that afforded matched doses across sites. For example, the noise dose of 6Q results in a CDNL of 42.48 at Site A. An attempt was made to generate combinations that would result in a CDNL of 42 at other sites, using slight modifications to existing combinations at Site A. A similar CDNL of 42.62 can be seen at Site B as a result of 2L and 4 M. Pairing the Site A noise dose impact for 6Q with Site B impact for 2L, 4M in the design affords the potential to compare a similar noise dose across two sites for two different combinations of single events.

The overall flight parameters act as constraints on the process to balance the noise dose. The selection of combinations is defined by the design constraints. The constraints are as follows:

- 21 flights total
- 2 to 3 flights per day
- Only 1 day with 4 flights
- 8 booms per day with flights distributed throughout the day from 7 AM to 5 PM
- Provide comparison across days
- Schedule majority of Quiet and Lo booms in AM due to anticipated cooler temperatures

Changes in noise combinations directly affect the number of booms per day, and can affect the number of flights. Quiet and Lo level booms were scheduled throughout the day, but an attempt was made to schedule the majority of them in the cooler temperatures in the AM. Each change in a combination affects the overall balance in terms of number of booms, number of flights, the distribution of level across the daily schedule, and comparison of daily doses. Combinations were eliminated if they resulted in changes to the overall design constraints. The combinations that provided balance were included.

Table 8-6 Subset of potential cumulative noise dose combinations

Site A Galveston Combinations			
Levels	Thumps	PLDN	CDNL
3Q, 1L	4	32.74	42.25
6Q	6	32.08	42.48
4Q,1L	5	33.32	42.96
4Q,3L	7	36.33	45.52
2Q,3L,1M	6	38.22	46.52
2Q, 1L,1M	4	36.53	44.62
2Q,2L, 2M	6	39.27	47.17
6L	6	38.08	46.78
1Q,4L, 1M	6	38.72	46.98
2Q,1L,3M	6	40.11	47.73
3L,2M	5	39.53	47.33
2Q, 3L,2M	7	39.79	47.78
2Q,2L, 3M	7	40.54	48.27
2L,4M	6	41.36	48.83
1Q,2L,4M	7	41.45	49.00
7M	7	43.05	50.25
1L,2M,1H	4	44.97	49.99
2Q, 1L,3M,1H	7	45.42	50.82
2Q,2L,2M,2H	8	47.60	52.44
2Q,4M,2H	8	47.87	52.78
2L,2M,3H	7	49.11	53.64
3L,2M,3H	8	49.17	53.79
1Q,1L,1M, 3H	6	48.91	53.24
1Q,1L,2M, 3H	7	49.07	53.54
1Q,1M, 4H	6	50.06	54.23
2L,6H	8	51.74	55.86
2M,6H	8	51.85	56.02

Table 8-7 Comparison of CDNL for combinations across sites

Site Compare		Site A	Site B	Site C
Levels	Thumps	CDNL	CDNL	CDNL
3Q, 1L	4	42.25		
6Q	6	**42.48**	Not within footprint	
4Q,1L	5	42.96		
4Q,3L	7	**45.52**		
6L	6	46.78		
2Q,3L,1M	6	46.52	36.60	
2Q, 1L,1M	4	44.62	36.60	
2Q,2L, 2M	6	47.17	39.61	
1Q,4L, 1M	6	46.98	36.60	
2Q,1L,3M	6	47.73	41.37	
3L,2M	5	**47.33**	39.61	
2Q, 3L,2M	7	**47.78**	**39.61**	
2Q,2L, 3M	7	48.27	41.37	
2L, 4M	6	**48.83**	**42.62**	
1Q,2L,4M	7	49.00	**42.62**	
7 M	7	50.25	**45.05**	
1L,2M,1H	4	49.99	**45.35**	37.80
2Q, 1L,3M,1H	7	50.82	45.89	37.80
2Q,2L,2M,2H	8	52.44	**47.74**	**40.81**
2Q,4M,2H	8	52.78	48.36	40.81
2L,2M,3H	7	53.64	49.27	42.57
3L,2M,3H	8	53.79	49.27	42.57
1Q,1L,1M, 3H	6	53.24	49.03	42.57
1Q,1L,2M, 3H	7	53.54	49.27	**42.57**
1Q,1M, 4H	6	54.23	50.21	43.82
2L,6H	8	55.86	51.78	45.58
2M,6H	8	56.02	52.04	45.58

8.5 Variables Balanced across the Design

The noise exposure design balanced exposure across test days, the number of Q, L, M and H booms across the design, separation of booms between AM and PM flight sequences, and distribution of booms among the sequences. An attempt was made to balance the distribution of the design across test days and over time periods within test days. Atmospheric heating and potential increase in winds during the day has a larger effect on the ability to deliver low level booms. As such, the lowest level booms are primarily in the morning, with only a few occurring later in the day. A summary of the design is presented in Table 8-8 and Table 8-9. The design includes flexibility for day-of-flight modifications via substitution of daily flight operations depending on weather conditions or other factors to help maintain balance of the design.

Table 8-8 Distribution of booms over test day and level

Test Day	Flights	Quiet	Lo	Md	Hi	Thump Total
1	3	4	3			7
2	2	6				6
3	2		6			6
4	2		3	2		5
5	3	2	3	2		7
6	3		2	4		6
7	3			7		7
8	3	2	2	2	2	8
9	Make up					
10	Make up					
Total	21	14	19	17	2	52

Table 8-9 Distribution of booms over time and level

Time	Day	Quiet	Lo	Med	Hi	Total
(8-9)	3,7		3	2		5
(9-10)	1,6	2	2	1		5
(10-11)	2,5	3	1	1		5
(11-12)	4,6,8	2	3	2		7
(12-1)	3,5	2	4			6
(1-2)	1,4,8	1	3	2	1	7
(2-3)	2,7	3		2		5
(3-4)	1,7,8	1	2	4	1	8
(4-5)	5,6		1	3		4
Total		14	19	17	2	52

8.6 Range of cumulative dose levels

The cumulative daily noise dose represents a sum of the single event exposures for each test day and will be calculated for several cumulative metrics. The selected daily dose range across all communities is from 40 to 54 CDNL. In comparison to the range in Table 8-5, combinations in the loud range were not included in the design. The anticipated daily range at Galveston is from 42 to 52 CDNL which corresponds to a range of 32 to 48 PLDN. The range of values across communities and at each site is provided in Table 8-10, through Table 8-13. The range of noise impact across all of the communities is quieter than the noise impact at Galveston due to the distance of the communities from the different dive points. For example, the cumulative level for 2Q, 2L, 2M, 2H, at Galveston is in the moderately loud range, shaded in turquoise with a CDNL at 52.44. The same single event combination on Tiki Island is in the quiet range, shaded in teal, and at La Marque Cemetery that combination drops into the quietest range, shaded in yellow.

Table 8-10 Range of cumulative noise metrics across communities

QSF 2018 Planning		
Perception	CDNL	Range
Quietest	39.9 - 43.9	4.0
Quiet	44 -47.9	4.0
Moderate	48 - 50.9	3.0
Mod. Loud	51-53.9	3.0

Table 8-11 Range of cumulative noise metrics at Galveston

Site A Galveston Combinations			
Levels	Thumps	PLDN	CDNL
6Q	6	32.08	42.48
4Q,3L	7	36.33	45.52
6L	6	38.08	46.78
3L,2M	5	39.53	47.33
2Q, 3L,2M	7	39.79	47.78
2L,4M	6	41.36	48.83
7M	7	43.05	50.25
2Q,2L,2M,2H	8	47.60	52.44

Table 8-12 Range of cumulative noise metrics at Tiki Island

Site B Tiki Island Combinations			
Levels	Thumps	PLDN	CDNL
6Q	6	Not within footprint	
4Q,3L	7		
6L	6		
3L,2M	5	30.01	39.61
2Q, 3L,2M	7	30.01	39.61
2L,4M	6	33.02	42.62
7M	7	35.45	45.05
2Q,2L,2M,2H	8	41.43	47.74

Table 8-13 Range of cumulative noise metrics at La Marque Cemetery

Site C: La Marque Cemetery Combinations			
Levels	Thumps	PLDN	CDNL
6Q	6	Not within footprint	
4Q, 3L	7		
6L	6		
3L,2M	5		
2Q, 3L,2M	7		
2L,4M	6		
7M	7		
2Q,2L,2M,2H	8	31.61	40.81

An attempt was made to identify combinations that afforded comparisons of the same CDNL impact across communities on different days. The combination of 4Q and 3L results in a 45.52 CDNL on Galveston. A 45.05 CDNL is achieved at Tiki Island with a combination of 7M. The "If-then" design implementation required that the noise dose exposure not to exceed 80 PLdB per event for days 1 through 3. As such, only Quiet and Lo level thumps were used during those days. At the upper limit, the the noise plan exposure was not to exceed 95 PLdB per event for Day 8. As such, Day 8 is the only day presenting Hi level booms. Sonic thumps at lower levels were included throughout the design. This design was predicated on the assumption that the Q, L, and Med level booms would not result in high levels of annoyance as assessed by the daily summary of annoyance results. In the event that Med booms (84 PLdB) result in higher annoyance a second test matrix was developed that includes only lower level booms. It is presented after the preferred test matrix. Field levels and impact may vary slightly from the predicted values. We anticipate that there will be some rumbles from evanescent waves at both Tiki Island and at La Marque that will make cumulative levels higher than presented by these tables. The design affords paired comparisons at Galveston across test days and the potential for comparisons to other communities on different test days.

8.7 Test matrix with range of noise doses (single event and cumulative)

The noise dose design was optimized for the Galveston site location, spacing across the CDNL levels that were possible using different boom combinations. The design details included the test day, the date, the day of the week, the time of day that the flight sequence is scheduled, the number of booms per flight sequence, the level of the booms in each flight sequence, the total flights per day, the daily exposure given as Lo, Med and Hi, the total of booms per day, and the associated metric level for the different boom combinations. The noise dose flight schedule was developed in such a way that it could be modified daily to afford evenly distributed noise doses across the possible range. The level and number of booms represented in the design were modified using the following boom constraints.

- Boom Targets based on Galveston Site: Quiet, ~0.13, Lo ~ .2 psf, Med ~ .28 psf, Hi ~ .53 psf
- Target goal of CDNL levels on Galveston that increase as defined in "If-then" dose progression

- Target goal to include one distinct CDNL (47) that repeats on 2 different test days
- Identified combinations that can compare between communities for different days
- Target a minimum of 20 to 30 minutes spacing between booms

The schedule in Table 8-14 presents the CDNL levels that are lower earlier in the test period. The selected CDNL values afford comparison across a range of values. The noise design varied the spacing of the booms with realistic limits on flight constraints, keeping all flights within the 7 AM to 5 PM flight

Table 8-14 Noise Dose Design and Field Test Schedule

Test Day	Date	Week Day	AM Booms/ /Flight	Level	PM Booms/ /Flight	Level	Flights/Day	Daily Exposure	Booms/Day	QSF 18 CDNL	
1	5-Nov	M			(1-2)	1Q, 1L					
Galveston Noise Dose					2//1						
			(9-10)	2Q, 1L	(3-4)	1Q, 1L					
			3//1		2//1		3	4Q, 3L	7	45.52	
2	6-Nov	T	(10-11)	3Q	(2-3)	3Q					
	Election Day		3//1		3//1		2	6Q	6	42.48	
3	7-Nov	W	(8-9)	3L	(12-1)	3L					
			3//1		3//1		2	6L	6	46.78	
4	8-Nov	Th									
Respite								Respite			
5	9-Nov	F	(11-12)	2L,1M	(1-2)	1L,1M					
			3//1		2//1		2	3L,2M	5	47.33	
6	10-Nov	Sat	(10-11)	1L,1M	(12-1)	2Q,1L					
			2//1		3//1						
					(4-5)	1L,1M					
					2//1		3	2Q,3L,2M	7	47.78	
7	11-Nov	Sun	(9-10)	1L, 1M							
			2//1								
			(11-12)	1L, 1M	(4-5)	2M					
			2//1		2//1		3	2L,4M	6	48.83	
8	12-Nov	M	(8-9)	2M	(2-3)	2M					
			2//1		2//1						
					(3-4)	3M					
					3//1		3	7M	7	50.25	
9	13-Nov	T			(1-2)	1L,1M, 1H					
					3//1						
			(11-12)	2Q	(3-4)	1L,1M, 1H					
			2//1		3//1		3	2Q,2L,2M,2H	8	52.44	
10	14-Nov	W	Weather make up								
						Total Flights	21				

period. The first flight can take off at 8 AM and the last flight occurs at 4 PM. The field test noise goal is to meet the target Daily Noise Dose (e.g., 42.48 CDNL) by achieving the designated boom combinations (e.g., 6Q). The day/time of the boom, the boom order and the boom spacing may change on a daily basis due to operational considerations. The time periods are distributed throughout the day and over the 2-week period, however, they can vary based on situational and weather conditions. The pilot can vary the spacing between the booms, provided the spacing remains random.

The daily and single event noise doses included in the design were selected to provide a balance over the range of potential noise doses as well as a balanced distribution across each day and across the entire test period. Some of these single event and daily pairings are highlighted in Table 8-14. The inclusion of a daily dose of 6L, the combination 3L, 2M, and the combination 2Q, 3L, 2M provides a dose of ~47 at Site A using different combinations for different days. The CDNL dose of 47 at site A is matched with a CDNL dose of ~47 at Site B by including 2Q, 2L, 2M, 2H which results in a 47.74 at Site B. The daily combination also includes a day with 6Q that can be compared to daily doses of 6L and 7M. These provide a similar number of booms across the day but of different levels on each day.

The selection of this set of daily noise doses provided the potential for comparison of similar single event noise doses within a given day, or across days. A single event consisting of 1Q, 1L is presented at different times, and can be compared to the slightly incremented dose of 2Q, 2L. The single event doses of 3Q, 3L and 3M are scattered throughout the design. The dose of 1L, 1M can be compared to itself or to the incremented 1L, 1M, 1H. It is acknowledged that situational variables for each single event and each day can have an impact on the annoyance perception. Creating a noise dose design that is balanced across multiple variables affords the potential to compare both single event and daily noise dose for various parameters.

8.8 Test Matrix with lower range of doses (cumulative and single event)

The previously presented design is the preferred design, and follows the "If Then" gradual increase of noise dose across the test design. It was predicated on the assumption that the Q, L, and Med level booms would all not result in high levels of annoyance as assessed by the daily summary of annoyance results. The following design includes only Q and Lo level booms and is to be implemented in the event that the Med level booms (84 PLdB) result in higher annoyance. The same process as described above was implemented to identify the combinations that are presented in the Lower level test matrix below. The range of values across communities is provided in Table 8-15. Because only Quiet and Lo level booms were used for this lower level design, both Site B: Tiki Island and Site C: LaMarque Cemetery are not within the boom footprint.

Table 8-15 Range of lower level cumulative noise metrics across communities

Site Compare		Site A	Site B	Site C
Levels	Thumps	CDNL	CDNL	CDNL
4Q	4	40.72	Not within footprint	
3Q, 1L	4	42.25		
6Q	6	42.48		
4Q,1L	5	42.96		
2Q, 2L	4	43.38		
3Q,2L	5	43.93		
4Q,2L	6	44.42		
4Q, 3L	7	45.52		
5Q,3L	8	45.86		
6L	6	46.78		

The lower level noise design was implemented using the same daily schedule as was presented for the preferred design. This was done to readily support substitutions of noise dose from the lower level design into the preferred design as warranted. The design is presented in Table 8-16. This design includes only Quiet and Lo single events, with subsequent reduction in the cumulative levels.

Table 8-16 Lower Level Noise Dose Design and Field Test Schedule

Test Day	Date	Week Day	AM Booms/ /Flight	Level	PM Booms/ /Flight	Level	Flights/Day	Daily Exposure	Booms/Day	QSF 18 CDNL
1	5-Nov	M			(1-2)	2Q				
Galveston Lower Level Noise Dose					2//1					
			(9-10)	3Q	(3-4)	2Q				
			3//1		2//1		3	7Q	7	43.15
2	6-Nov	T	(10-11)	3Q	(2-3)	3Q				
	Election Day		3//1		3//1		2	6Q	6	42.48
3	7-Nov	W	(8-9)	2Q,1L	(12-1)	2Q,1L				
			3//1		3//1		2	4Q,2L	6	44.42
4	8-Nov	Th								
Respite								Respite		
5	9-Nov	F	(11-12)	2Q,1L	(1-2)	1Q,1L				
			3//1		2//1		2	3Q,2L	5	43.93
6	10-Nov	Sat	(10-11)	1Q,1L	(12-1)	3L				
			2//1		3//1					
					(4-5)	1Q,1L				
					2//1		3	2Q, 5L	7	46.59
7	11-Nov	Sun	(9-10)	2L						
			2//1							
			(11-12)	2L	(4-5)	2L				
			2//1		2//1		3	6L	6	46.78
8	12-Nov	M	(8-9)	2Q	(2-3)	2Q				
			2//1		2//1					
					(3-4)	3L				
					3//1		3	4Q, 3L	7	45.52
9	13-Nov	T			(1-2)	3Q				
					3//1					
			(11-12)	2Q	(3-4)	3L				
			2//1		3//1		3	5Q,3L	8	45.86
10	14-Nov	W	Weather make up							
						Total Flights	21			

8.9 Comparison of noise dose planning with prior field tests

The range of planned cumulative metric values for QSF 18 is compared with the values presented in WSPR and with the findings of previous studies, several of which are summarized in CHABA (1996). The CHABA report presented finding from five prior studies. Two were sonic boom studies: Oklahoma City reported by Borsky (1965), and NASA reported by Fields et al (1994). Three were blast noise assessment studies: Ft. Bragg reported by Schomer (1981), Ft. Lewis reported by Schomer (1985), and Sweden reported by Rylander and Lundquist (1996). Table 8-17 presents the range of cumulative metrics for the CHABA (1996), WSPR 2011 datasets and the planned QSF 18 CDNL noise design.

Table 8-17 Comparison of CDNL impact across prior field tests

The QSF field levels may be different than predicted due to rumble of an evanescent boom

Source	Team	Approx. CDNL
Low Boom	QSF18 Planning	39.8 -57.5
Low Boom	WSPR NASA, 2011 EAFB	47.4 – 56.9
Sonic Boom	Borsky 1965, Ok City	54 – 64
Sonic Boom	Fields et al., 1994 Nellis AFB	38 -56
Artillery	Schomer 1981, Ft. Bragg	58 – 70
Gunfire	Sweden Rylander Lundquist, 1996	41 – 68
Artillery	Schomer, 1985, Fort Lewis	51 – 65

The QSF18 noise planning levels across communities fall below the levels previously observed in both WSPR and prior tests. The QSF18 level across communities is lower than the range that was for planned for the WSPRRR field test design during the conduct of the WSPR test. (see Tables 8-18, 8-19 and 8-20). The planned range at Galveston is louder than that observed across all of the communities and it approximates the range observed in the WSPR field test. Annoyance data was gathered for both the WSPR and CHABA prior tests, with the WSPR 2011 daily levels shown in

Table 8-18. It is presented here as an indicator of dose response relationships observed for higher levels of noise impact in prior field studies. presents the CHABA (1996) datasets in addition to the WSPR data, expressed in terms of the percent highly annoyed as a function of the yearly averaged metric C-weighted Day-Night Level (CDNL) (Page *et al.,* 2014). The annoyance ratings for WSPR are significantly lower than was observed in Fields (1994) or Rylander and Lundquist (1996) but are consistent with the data from the other researchers. The WSPR team used noise measurements obtained during the same period as the social surveys, while some of the prior studies relied on measurements from different time periods or from predicted levels.

Table 8-18 WSPR Low Boom Levels

WSPR 2011 Low Booms		
Booms	Daily DNL	CDNL
3L, 2M, 0H	21.8	47.4
4L, 2M, 0H	21.8	47.6
4L, 1M, 1H	27.3	49.6
5L, 1M, 1H	27.3	49.8
0L, 4M, 2H	30.8	53.2
2L, 4M, 2H	30.8	53.3
2L, 0M, 4H	32.6	53.7
3L, 3M, 4H	33.1	54.9
2L, 2M, 6H	34.6	56
1L, 1M, 8H	35.7	56.9

Table 8-19 Range of cumulative noise metrics for preferred design at Galveston

Site A Galveston Combinations			
Levels	Thumps	PLDN	CDNL
6Q	6	32.08	42.48
4Q,3L	7	36.33	45.52
6L	6	38.08	46.78
3L,2M	5	39.53	47.33
2Q, 3L,2M	7	39.79	47.78
2L,4M	6	41.36	48.83
7M	7	43.05	50.25
2Q,2L,2M,2H	8	47.60	52.44

Table 8-20 Range of cumulative noise metrics across communities

QSF 2018 Planning		
Perception	CDNL	Range
Quietest	39.9 - 43.9	4.0
Quiet	44 -47.9	4.0
Moderate	48 - 50.9	3.0
Mod. Loud	51-53.9	3.0
Loud	54-57.5	3.5

The CHABA, WSPR and WSPRR planning CDNL ranges are presented in Figure 8-1 to provide background for the QSF18 noise dose design. The annoyance data gathered from prior field tests is presented to provide further context as to annoyance response that can be anticipated as a function of CDNL level.

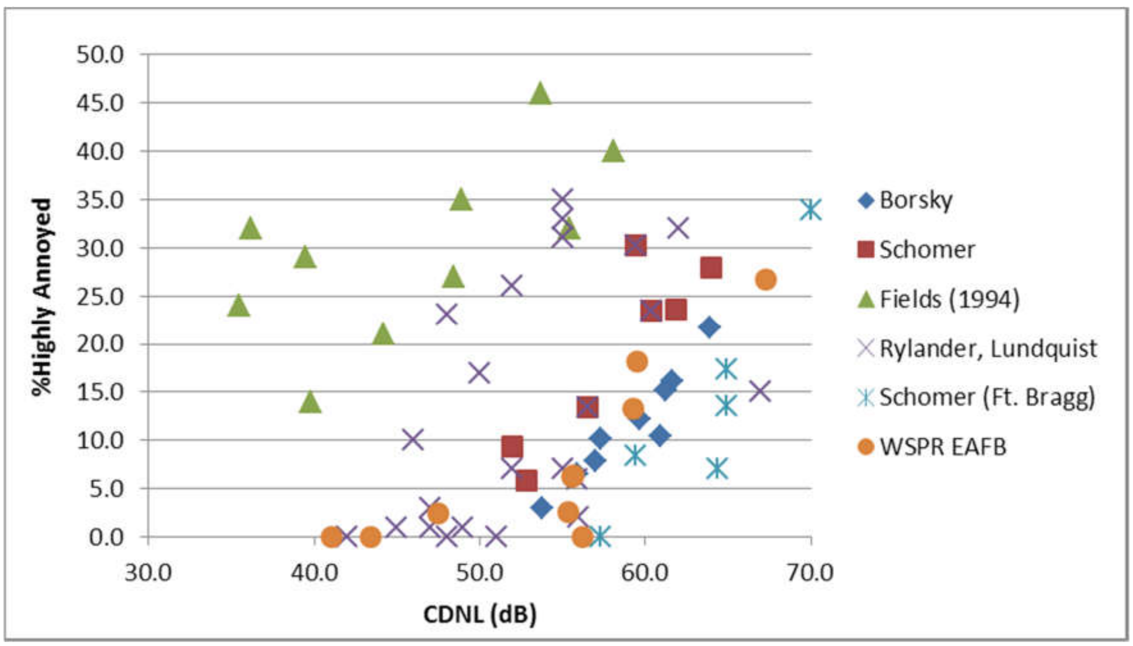

Figure 8-1. Comparison of WSPR exposures to related field studies (Source: Page et. al 2014).

9. Sonic Boom Objective Measurements

9.1 Instrumentation List

A single SBUDAS noise monitor is depicted in Figure 9-1. It consists of two GRAS 41AO microphones on sound boards connected to a National Instruments cRIO and WR-21 Cellular Router contained in an electronics enclosure. Power is supplied from a 12 Volt marine battery which is continuously charged through a solar panel. The entire arrangement takes up approximately 16 square feet of space. Twelve SBUDAS Noise Monitors will be utilized during QSF18.

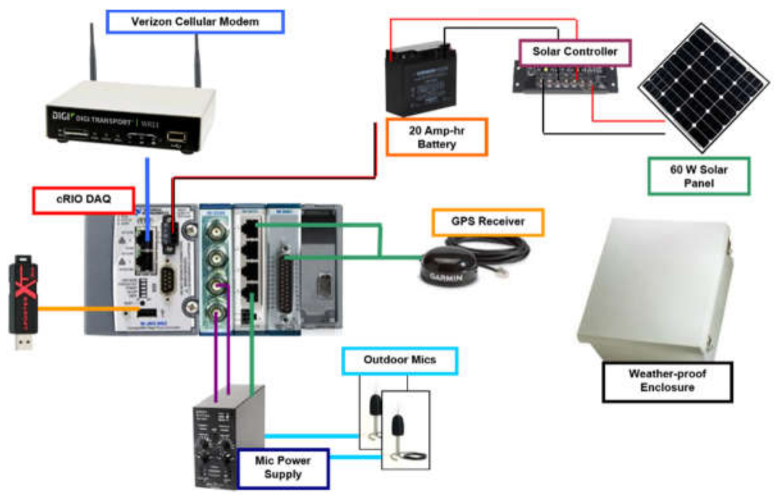

Figure 9-1 SBUDAS Noise Monitor

Table 9-1. Instrument List

Component	Description
NI cRIO-9023	CompactRIO Controller
NI 9234	DSA Module
NI 9870	Series Serial Interface
NI 9381	Multifunction I/O Module
G.R.A.S. 40AN	Low Freq., Free-field Microphone
G.R.A.S. 26AJ	Preamplifier
G.R.A.S. 12AQ	Power Module
DIGI WR21	LTE Cellular Modem
URB12200	Lithium Ion Battery
Aleko 12V 60W Solar Panel	Solar Panel

The network configuration for each of the SBUDAS noise monitors is presented in Table 9-2. In addition the APS/GAC team will provide three microphone calibration devices.

Table 9-2 SBUDAS Network Configuration

	User	Password	WR21 IMEI	Static IP	WR21 eth0 ip	Instrument IP	Instrument Desc	Instrument Name
1	root	WsPrRr	359225054464888	166.159.103.008	192.168.7.1	192.168.7.100	Computer	BASE
2	root	WsPrRr	359225053163739	166.239.138.140	192.168.1.1	192.168.1.100	NI cRIO	ALPHA
3	root	WsPrRr	359225054963319	166.157.019.179	192.168.2.1	192.168.2.100	NI cRIO	BRAVO
4	root	WsPrRr	359225052673670	166.239.138.139	192.168.3.1	192.168.3.100	NI cRIO	CHARLIE
5	root	WsPrRr	359225052672722	166.239.138.138	192.168.4.1	192.168.4.100	NI cRIO	DELTA
6	root	WsPrRr	359225054963335	166.157.019.178	192.168.5.1	192.168.5.100	NI cRIO	ECHO
7	root	WsPrRr	359225055271159	166.157.019.177	192.168.6.1	192.168.6.100	NI cRIO	FOXTROT
8	root	WsPrRr	359225056392483	166.141.178.35	192.168.8.1	192.168.8.100	NI cRIO	GOLF
9	root	WsPrRr	359225056390750	166.161.233.130	192.168.9.1	192.168.9.100	NI cRIO	HOTEL
10	root	WsPrRr	359225056391634	166.141.178.34	192.168.10.1	192.168.10.100	NI cRIO	INDIA
11	root	WsPrRr	359225056266950	166.141.178.33	192.168.11.1	192.168.11.100	NI cRIO	JULIET
12	root	WsPrRr	359225056393853	166.141.178.32	192.168.12.1	192.168.12.100	NI cRIO	KILO
13	root	WsPrRr	359225056266489	166.141.178.36	192.168.13.1	192.168.13.100	NI cRIO	LIMA

Two host station computers will be utilized with each connected to the network via a WR-21 and controlling six SBUDAS. Both host station computers will be located at the Scholes Airport on Galveston Island. Additionally two laptop computers will be configured with the host station LabView application. These computers can serve as backup host stations and additionally they can be directly connected to a SBUDAS noise monitor and operated by a field engineer in the event that the noise monitor is located in a position that is challenged by cellular connectivity.

9.2 Microphone Locations

During the site visit there were approximately 50 candidate noise monitor locations investigated by team personnel. Each site was reviewed for cellular connectivity, ambient noise, security and characteristics relevant to safe and effective operation of the SBUDAS noise monitors. The sites were rated on a scale of A, B, or C if acceptable as shown in Figure 9-2. The ultimate locations for noise monitor placement of noise monitors will be driven by recruiting results, however the number of acceptable locations is a reflection of the flexibility we have in our ability to place these instruments.

A corresponding subset of these locations recommended as candidate locations by AFRC are shown in Figure 9-2 and detailed in Table 9-5.

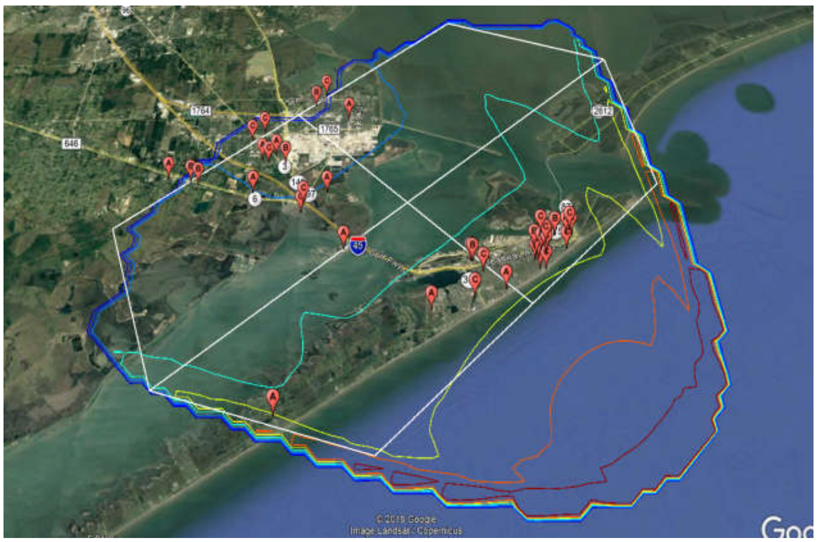

Figure 9-2 Noise Monitor locations investigated during Galveston site visit April 2018.
Each location was rated on a scale of A,B,C based on security, ambient noise, and cellular connectivity

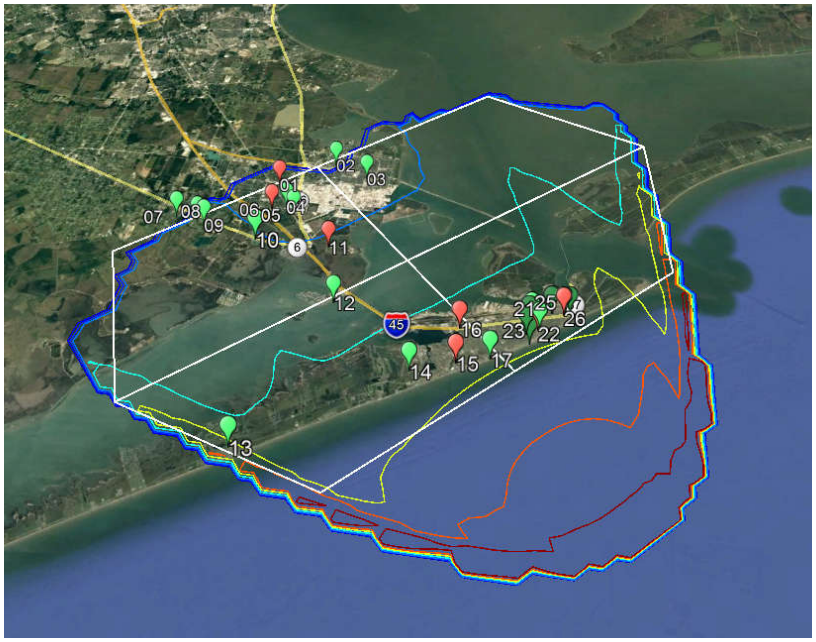

Figure 9-3 Noise Monitor locations recommended by AFRC based on April 2018 Site Visit investigations. Green symbols indicate locations rated A or B, red symbols indicate locations rated C or F

Table 9-3 Candidate noise monitor locations recommended by AFRC. Green: first choice locations

SiteID	Map	Address	Location	Latitude	Longitude	Rating	Community type	**Scounting Report Page
1	https://goo.gl/maps/tyeWJmzKV4m	316 S Pine Rd, Texas City, TX 77591	Hopewell Missionary Baptist	29.380531	-94.964047	C	Residential	97,
2	https://goo.gl/maps/qKMWjQ9SVCn	1725 N Logan St, Texas City, TX 77590	Texas City Fire Department 25th st	29.401885	-94.931775	B	Residential	63,64
3	https://goo.gl/maps/VasKS7AsZ642	825 10th St N, Texas City, TX 77590	Texas City Fire Department 2	29.392975	-94.908984	A	Residential	70
4	https://goo.gl/maps/FFYhrgb2wJ12	598 Apricot St, La Marque, Texas	La Marque Cemetery	29.363193	-94.954457	A	Residential	93,94
5	https://goo.gl/maps/9Q5kzccUs1w	10 Main St, La Marque, TX 77568	UPS Customer Center	29.357725	-94.947941	B	Business	95,
6	https://goo.gl/maps/9VYSyETvh2t	2024 12th Ave, La Marque, TX 77568	Trinity Lutheran Church ELCA	29.36014	-94.962838	F	Residential	83, 101, 102
7	https://goo.gl/maps/3ebhUY3Daz72	7003 2nd St, Hitchcock, TX 77563	Hitchcock Volunteer Fire Dpt.	29.346487	-95.020392	A	Residential	74,75
8	https://goo.gl/maps/KysFqSt7bYJ2	7002 N Martin Luther King Ave, Hitchcock, Texas	Church	29.344276	-95.005999	B	Residential	85
9	https://goo.gl/maps/NnGqvGXYR9m	6538 N Martin Luther King Ave, Hitchcock, Texas	Missionary Baptist Church	29.342471	-95.001044	B	Business	91,92
10	https://goo.gl/maps/LDJ9zPF5DEw	4621 Crane St, Hitchcock, Texas	Galvastan County Water Control	29.33662	-94.965896	A	Residential	89,90
11	https://goo.gl/maps/f6bgYhLuqFU2	Campbell Bayou Rd, Galveston, TX 77554	Campbell Bayou Rd Intersection	29.336503	-94.919987	A		
12	https://goo.gl/maps/9CbrCbAQUts	628 Tiki Dr, Tiki Island, Texas	Tiki Village Fire Station	29.299023	-94.907254	A	Residential	66,71,72
13	https://goo.gl/maps/XA9E7qVaGSq	3902 Buccaneer Blvd, Galveston, TX 77554	Galvastan Fire Station #7	29.210125	-94.938587	A	Residential	50
14	https://goo.gl/maps/fno9uyUHqKn	8710 Cessna Dr, Galveston, TX 77554	Galvastan Fire Station #4	29.263121	-94.856428	A	Mixed Use	48,
15	https://goo.gl/maps/jd5kPg1GHN12	2506 65th St, Galveston, TX 77551	Calvary Catholic Cemetery	29.271183	-94.832232	C	Business	53, 54
16	https://goo.gl/maps/fxyxEuC74nu	5728 Ball St, Galveston, TX 77551	56 Judicial Court	29.292069	-94.833121		Residential	40,45
17	https://goo.gl/maps/r4kCiSCFNko	4555 Fort Crockett Blvd, Galveston, Texas	National Marine Fisheries Services	29.275765	-94.814169	A	Mixed Use	52
18	https://goo.gl/maps/ueS9XT8xQFq	2222 28th St, Galveston, TX 77550	Menard Park	29.287801	-94.793635	B	Mixed Use	29,30
19	https://goo.gl/maps/dW9Y888wUwS2	2704 Avenue O, Galveston, TX 77550	Kempner Park	29.293464	-94.795921	B	Mixed Use	31,32
20	https://goo.gl/maps/V5tQ5HkfwW42	2514 Sealy Ave, Galveston, TX 77550	Galvastan Fire Station #1	29.300532	-94.794994	B	Mixed Use	16,
21	https://goo.gl/maps/CwANKtYdzio	601 23rd Street Rear, Galveston, TX 77550	United States Postal Service	29.303037	-94.793565	A	Mixed Use	13, 14
22	https://goo.gl/maps/fuaVwAVMruz	1320 23rd Street Rear, Galveston, TX 77550	O'Connell High School	29.296912	-94.789752	B-C	Mixed Use	27,
23	https://goo.gl/maps/HMA78xTc2Kq	1315 21st St, Galveston, TX 77550	The Bryan Museum	29.297367	-94.788781	B	Business	28
24	https://goo.gl/maps/a34Fs91LWjG2	1301 Market St, Galveston, TX 77550	Rosenburg House	29.308513	-94.782889	B	Business	7,8
25	https://goo.gl/maps/gfZJnJV4T8y	1248 Mechanic St Galveston, Texas	13th and Market NE corner	29.308826	-94.782252	B	Business	5,6
26	https://goo.gl/maps/Dx68KERYQBs	404 St Marys Blvd, Galveston, TX 77550	Rebecca Sealy Hospital parking lot	29.308572	-94.775964	C	Business	3,4
27	https://goo.gl/maps/pRs7oAdqGax	404 St Marys Blvd, Galveston, TX 77550	Rebecca Sealy Hospital parking lot	29.308828	-94.775315	B	Business	3,4
28	https://goo.gl/maps/9sgrtTk2Ee52	428 Church St, Galveston, TX 77550	Galveston Fire Station #2	29.309525	-94.772421	A	Business	1, 2
29	18.9%22W/@29.2096683,-94.9395836,	3902 Buccaneer Blvd, Galveston, TX 77554	Galveston Fire Station #7	29°12'36.45"N	94°56'18.91"W	A	Residential	49, 50

**Reference: NoiseMonitorInspection-SiteVisit-041618.pdf

Twelve SBUDAS noise monitors will be deployed. The selection of first choice locations, determined independent of recruiting results and based solely on distribution across the boom footprint are depicted in Figure 9-4 and highlighted in green in Table 9-4. This baseline plan is the first choice for noise monitor locations. Slight adjustment to these locations will be considered after recruitment occurs.

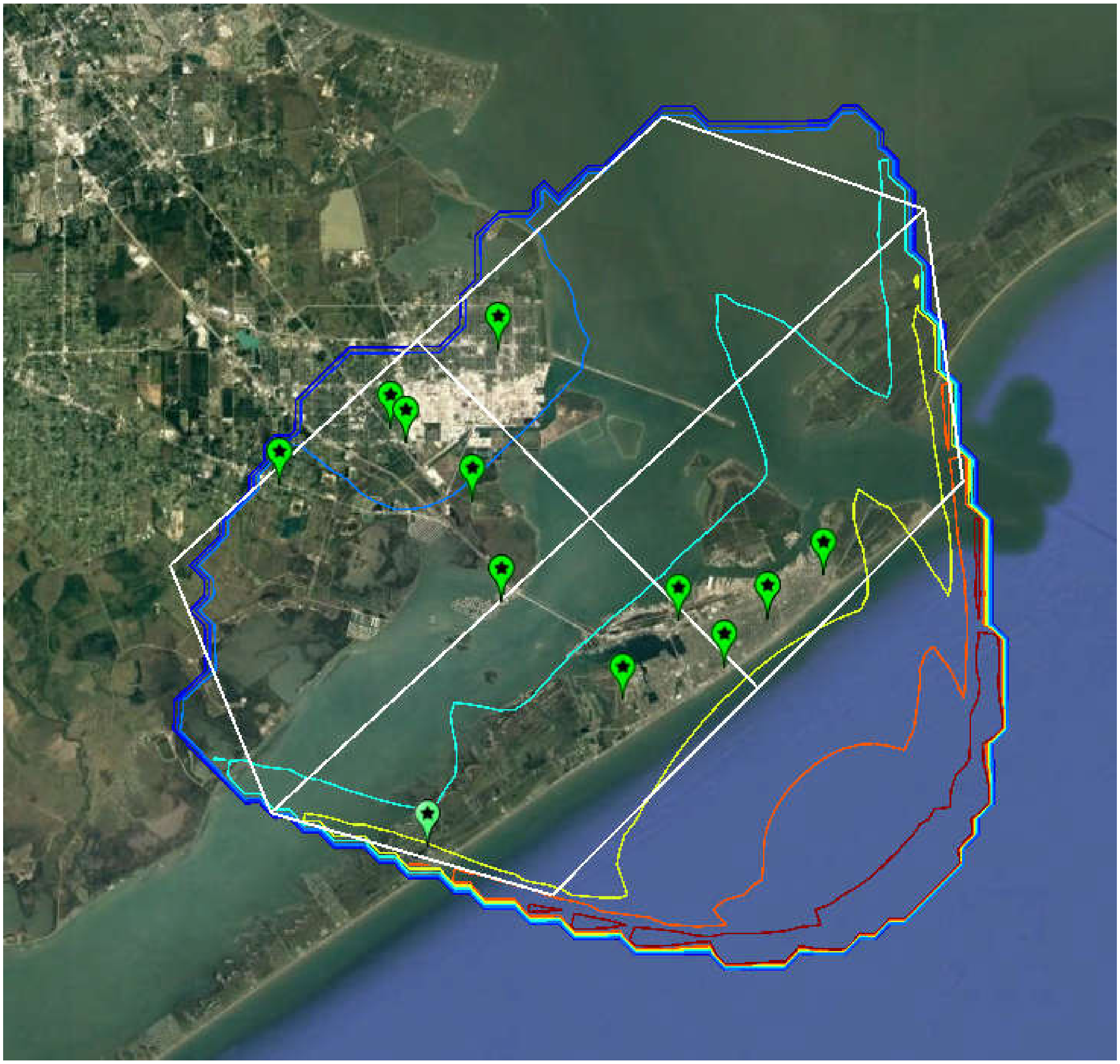

Figure 9-4 First choice noise monitor locations, independent of recruiting results

Cellular network connectivity is a key requirement for the effective operation of the SBUDAS noise monitors. As part of the Site Selection process, Galveston was evaluated with respect to cellular connectivity through the crowd sourcing application "OpenSignal" (https://opensignal.com/). OpenSignal data is collected from regular consumer smartphones and recorded under conditions of normal usage. Measurements are collected from millions of smartphones owned by normal people who have downloaded the OpenSignal app. Those measurements are taken wherever users happen to be, whether indoors or out, in a city or in the countryside, representing performance the way users experience it. The map of signal strength for the Verizon cellular network collected via this method is shown in Figure 9-5. Good cellular coverage was predicted across the QSF-18 area.

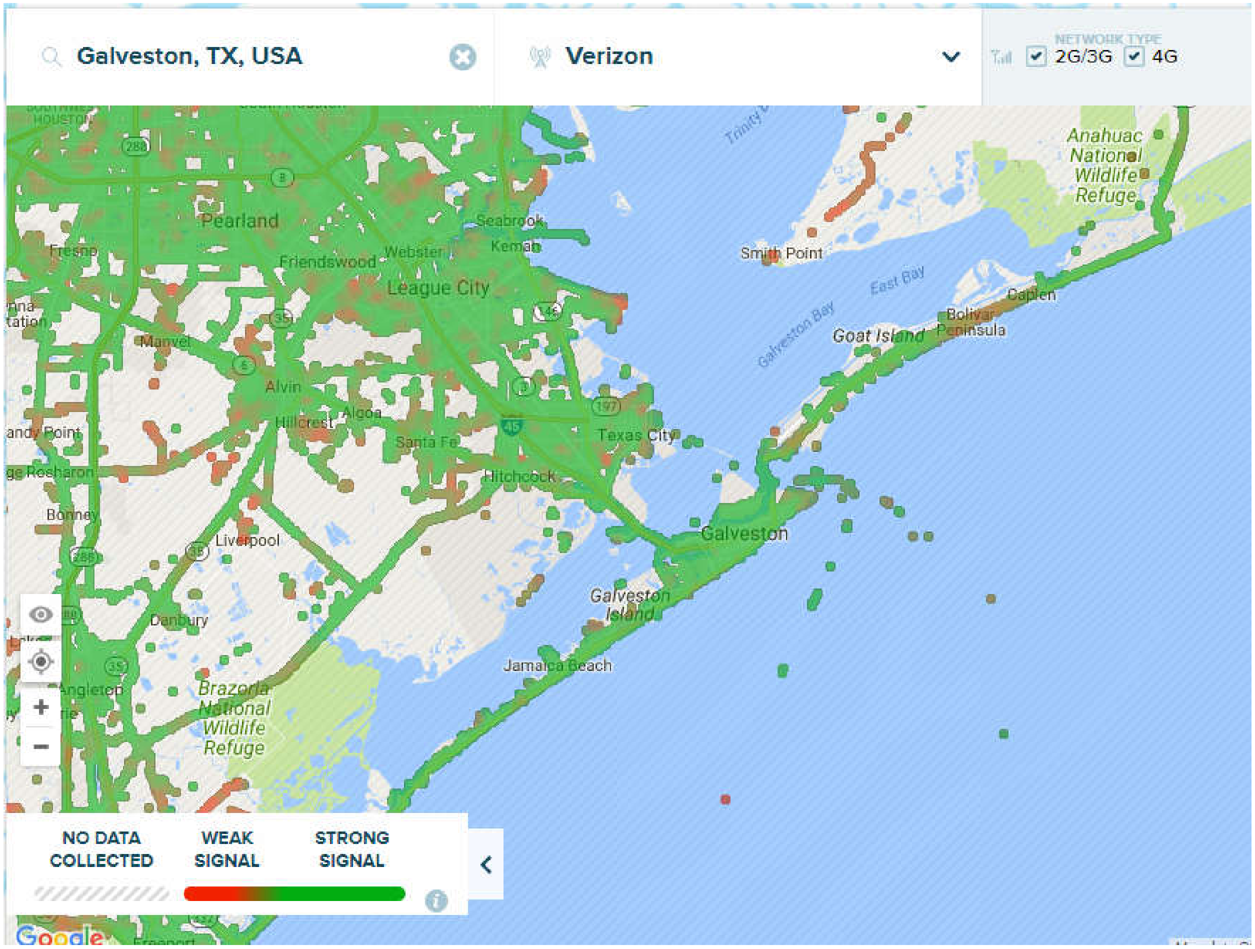

Figure 9-5 Verizon cellular network coverage (https://opensignal.com)
based on crowd source cellular phone performance collected through mobile phone app

At each candidate noise monitor location, investigators further evaluated the cellular signal utilizing a cell phone app: "Speedtest" by Ookla. As seen in Figure 9-6, the app measures the Mbps for both upload and download across the Verizon cellular network. 3 Mbps should be sufficient for SBUDAS operations.

Figure 9-6: OOKLA Speed Test (http://www.speedtest.net/)

Additionally seven candidate noise monitor locations were evaluated for cellular network connectivity using the WR-21 cellular routers from the SBUDAS Noise Monitors. For this test a computer/modem combination was stationed at Scholls Airport where the SBUDAS Host station is planned to be deployed and a second computer/modem combination was transported sequentially to each of the candidate noise monitor locations. The iPerf3 application was then run between the two locations over the Verizon cellular network with the results presented in Table 9-5. iPerf3 (https://iperf.fr/) is a tool for active measurements of the maximum achievable bandwidth on IP networks. It supports tuning of various parameters related to timing, buffers and protocols (TCP, UDP, SCTP with IPv4 and IPv6). For each test it reports the bandwidth, loss, and other parameters. iPerf was orginally developed by NLANR/DAST. iPerf3 is principally developed by ESnet / Lawrence Berkeley National Laboratory. It is released under a three-clause BSD license. Each test was run twice to evaluate network performance employing a SBUDAS Antenna and a WR-21 Dipole Antenna.

Table 9-4 Iperf Bandwidth Measurement results

		SBUDAS Antenna		Dipole Antenna	
Quadrant	location	Send	Receive	Send	Receive
	10 SEC Interval	Mbits/sec		Mbits/sec	
North	Gate B (Waste Water Treatment)	3.98	4.03	4.72	4.82
		4.82	4.97	4.61	4.69
		2.52	2.55	2.94	3.08
		2.94	2.93	3.04	3.11
		5.03	5.1		
		2.41	2.52		
	Average	3.616667	3.683333	3.8275	3.925
North	Texas City Fire, 1925 25th St.	2.94	2.97	2.41	2.52
		2.73	2.74	3.04	3.04
		4.93	5.05	4.82	4.88
		1.99	2.1	3.77	3.86
	Average	3.1475	3.215	3.51	3.575
West	1718 Crane Street			1.78	1.91
				2.41	2.4
				4.82	4.97
				4.72	4.84
	Average			3.4325	3.53
West	6538 Martin Luther King Ave	4.72	4.88	4.09	4.21
		3.25	3.33	2.94	3.06
		1.05	1.2	4.82	4.96
		4.92	4.99	4.72	4.92
		2.83	2.97		
	Average	3.354	3.474	4.1425	4.2875
West	Tiki Island	4.93	5.06	4.72	4.83
		3.36	3.43	2.94	3.04
		4.61	4.73	4.82	4.98
				4.93	5.06
	Average	4.3	4.406667	4.3525	4.4775
East	428 Church St Galveston (Fire Station)	4.19	4.28	3.99	4.11
		2.41	2.42	2.41	2.45
		3.67	3.78	4.4	4.5
	Average	3.423333	3.493333	3.6	3.686667
East	NOAA Galveston	2.52	2.6	4.71	4.82
		5.03	5.1	4.61	4.69
		4.61	4.74	2.94	3.08
		2.41	2.5	3.04	3.11
		4.72	4.93		
	Average	3.858	3.974	3.825	3.925

9.3 Operations

Two SBUDAS host station computers will each control six noise monitors. It is recommended that these computers along with their WR-21 Transport Cellular modems be located at Scholes Airport on Galveston Island.

Each SBUDAS noise monitor will be calibrated prior to the commencement of activities each morning and following the last flight in the afternoon. Calibration will require communications between a WSPRRR Engineer at the SBUDAS host station computer and another WSPRRR Engineer at the SBUDAS noise monitor location. The calibration steps include:

1. The host station operator will then place the SBUDAS monitor in continuous record mode for 30 seconds.
2. When the recording is complete the host station operator will note the presence of the recorded file on the SBUDAS noise monitor.
3. The host station operator will retrieve the noise file and review it on the host station for accuracy.
4. The host station operator will then inform the WSPRRR engineer at the noise monitor location.
5. The WSPRRR engineer at the noise monitor location will then move on to the next noise monitor to repeat this process.

The morning calibration each day will be time critical in that it needs to be accomplished to satisfy Go/No Go criteria for flight operations. As shown in Table 9-6, this can be accomplished with two field engineers travelling to each SBUDAS location provided that the process begins at 5:30 AM each day. If additional field engineers were available this process can be significantly compressed by minimizing the transit time between SBUDAS locations. End of day calibrations will be less time critical in that flight operations will have been completed.

Noise recordings during the QSF18 will be executed as follows:

1. Prior to each flight all SBUDAS monitors will be activated by the host station operator.
2. One minute prior to the commencement of the low boom all SBUDAS monitors will be placed in record mode.
3. All recordings will be completed within one minute of the conclusion of the low boom delivery.
4. Upon completion of the noise recordings, maximum overpressure and loudness (PLdB) will be calculated by each noise monitor and automatically sent to the SBUDAS host station for review by the WSPRRR PI.

Upon the completion of all flights for each day the flash drives from each noise monitor will be retrieved for archival purposes.

Table 9-5 Daily Noise Monitor Calibration

Two People Morning Calibration				
SBUDAS	Location	Time on station	Calibration Time	Transit Time
A	Galveston E	5:30:00 AM	0:05	0:15
B	Galveston E	5:50:00 AM	0:05	0:15
C	Galveston E	6:10:00 AM	0:05	0:15
D	Galveston W	6:30:00 AM	0:05	0:20
E	Galveston W	6:55:00 AM	0:05	0:20
F	Galveston W	7:20:00 AM	0:05	0:20
G	Texas City	5:30:00 AM	0:05	0:20
H	Texas City	5:55:00 AM	0:05	0:20
I	Texas City	6:20:00 AM	0:05	0:20
J	Hitchcock	6:45:00 AM	0:05	0:25
K	La Marque	7:15:00 AM	0:05	0:25
L	Tiki Island	7:45:00 AM	0:05	

9.4 Minimum Crew

Provided that there are no challenges with cellular connectivity, SBUDAS security, or equipment the minimum crew size for SBUDAS operations would be six engineers as shown in Figure 9-7. It is strongly recommended that at least two additional engineers be made available in the event that a SBUDAS requires attendance due to security or cellular connectivity issues and in the event of necessary trouble shooting.

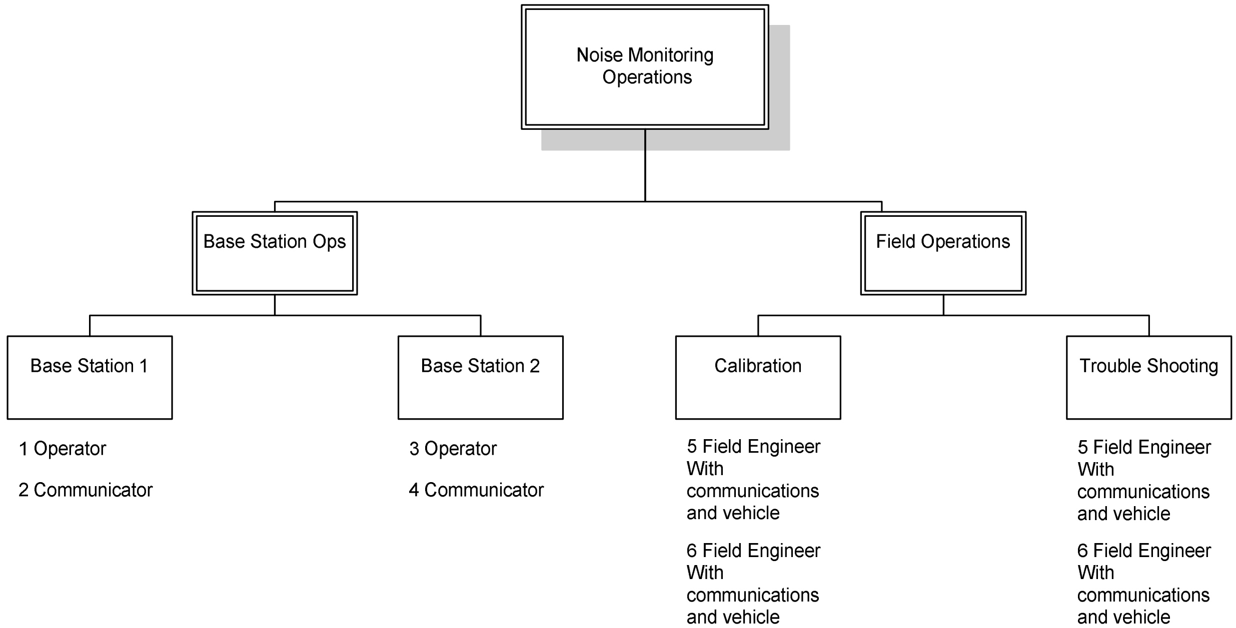

Figure 9-7 Noise Monitoring Operations Minimum Crew

9.5 Security

SBUDAS noise monitors will be deployed on a daily basis and retrieved upon the conclusion of flights on each day for storage at Scholes Airport.

10. Noise metrics

After recordings of the sonic booms are retrieved from the monitors, the recorded signals must be analyzed to compute the noise metrics of interest to the project. Because this test is going to utilize the LBDM (Haering *et al.,* 2005) to generate booms on the community the recorded event may contain a second boom. For the WSPR project (Page *et al.,* 2014) only the metrics for the first boom were calculated for estimating the dose response at participant households. The same will be done for participant locations during the upcoming measurements in Texas. Because some of the recorded events will be of low-amplitude sonic booms, ambient noise may be equal or greater than the sonic booms in some or all portions of the spectrum if the noise monitor is in a location with high enough background noise levels. The plans for consideration of the influence of ambient noise on the metrics calculated for a sonic boom and the length of the recorded signal analyzed is described in this section. In particular, we explore the issue of how to address ambient noise when the metrics calculated for the ambient are close to those calculated for the booms. Consider the graph in Figure 10-1 resenting the microphone signal recorded by the field-kit at site Alpha during the WSPR (Page *et al.*, 2014) measurements.

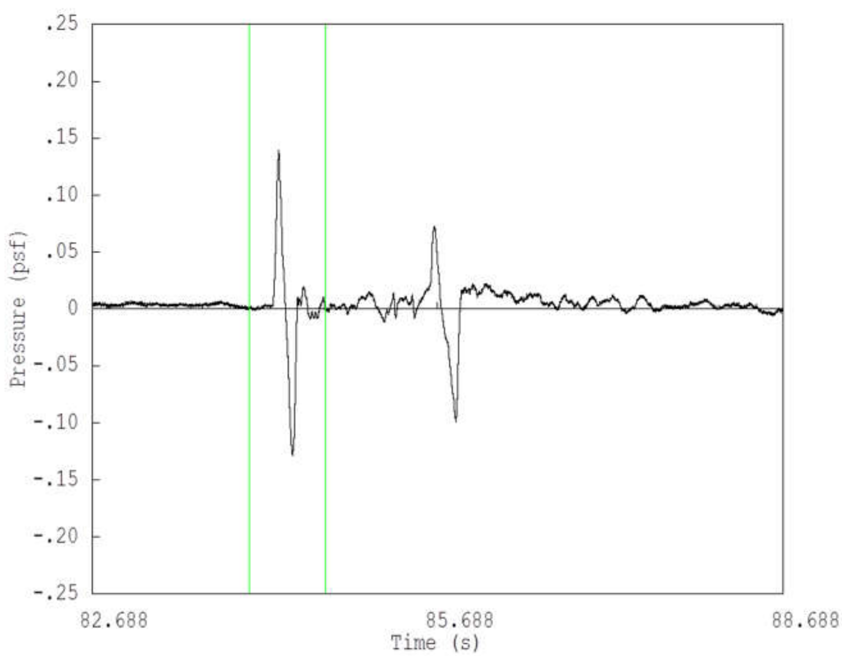

Figure 10-1 Example recording from a boom emitted during the low-boom dive maneuver with metrics shown for delineated portions of the signal. The first boom has a peak amplitude of 0.15 psf.

The A-weighted sound exposure level (ASEL) of the boom was less than one decibel greater than that of the preceding ambient. Starting with the first research using the LBDM (Sullivan, 2010) a test of the signal to noise ratio for keeping boom metrics required that the ASEL of the boom be at least 1 dB above the ambient; thus, metrics from this boom would not be used under this criteria. This criteria was applied for the first analysis of the WSPR data.

Regarding un-weighted and A-weighted spectra of the boom and ambient, when one considers that the measure at high frequencies is compressed, it becomes clear why the ASEL of the ambient, which has a comparable spectrum with the boom above 90 Hz, is nearly the same as the ASEL of the boom. The steepness of the boom's shocks contributes to the high-frequency content of its spectrum; however, the low-boom dive maneuver is executed so that the lower amplitude booms that hit the ground travel longer distances. Because of the further distances traveled, atmospheric absorption can cause a decrease in the peak overpressure of the boom by attenuating the higher frequencies. This can result in a rounding of the signature's shocks and a reduction of the peak overpressure. A comparison of the ASEL of the first boom and ambient from several events are shown in Figure 10-2.

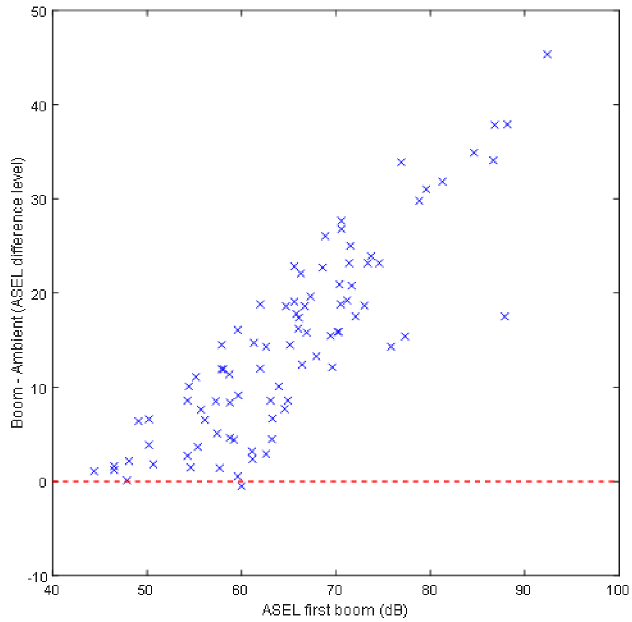

Figure 10-2 Comparison of the A-weighted level of the first sonic boom and the ambient (dBA) at Site Alpha during WSPR.

The dashed line in the figure represents when the ASEL of the first boom equals the ASEL of the ambient just preceding it. As can be seen, booms with lower A-weighted values are closer to the level of the preceding ambient. C-weighting does not attenuate the low-frequency portion of the spectrum as much as A-weighting. For comparison, A-weighting at 1.25 Hz is -140.59 dB while C-weighting is only -52.51 dB. As such, the C-weighted sound exposure level (CSEL) for all booms should be significantly greater than the ambient CSEL values. Figure 10-3 illustrates this.

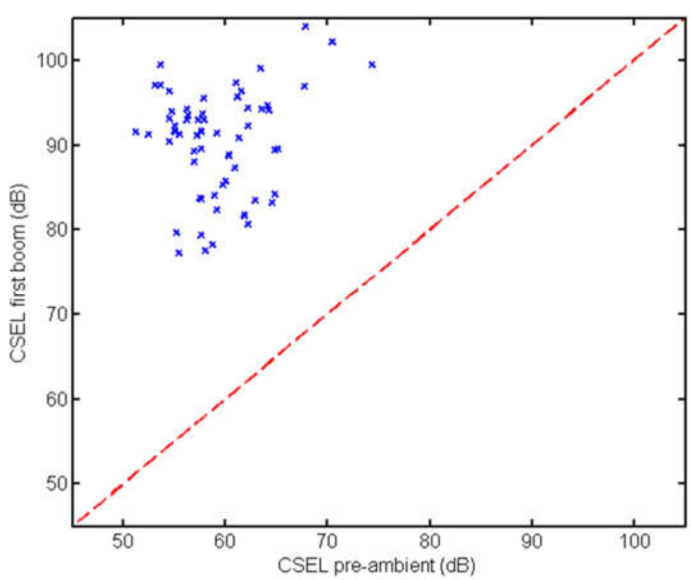

Figure 10-3 Comparison of the C-weighted level of the first sonic boom and the ambient (dBC) at Site Alpha during WSPR.

The lowest CSEL for a boom is more than 15 dB greater than the ambient CSEL. A similar plot of Steven's Mark VII perceived level of loudness (Stevens, 1972) for booms recorded at Site Alpha during WSPR versus the ambient level is shown in Figure 10-4.

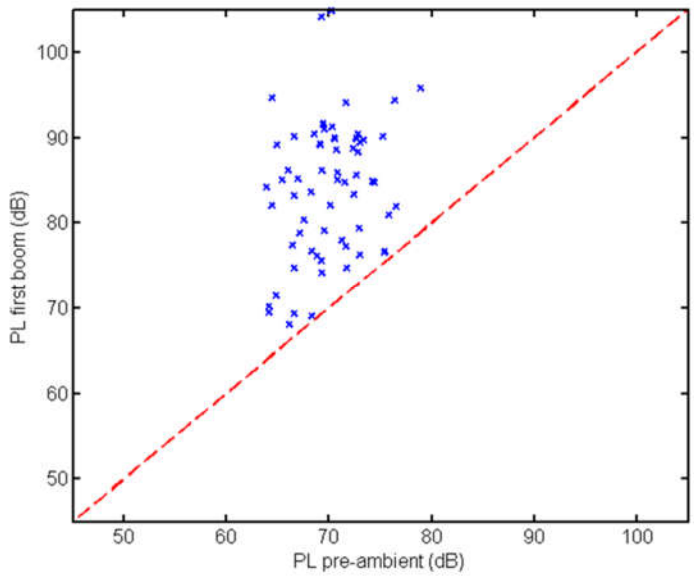

Figure 10-4 Comparison of the Perceived Level of the first sonic boom and the ambient (PLdB) at Site Alpha during WSPR.

Figure 10-4 shows that booms with lower perceived levels of loudness have comparable ambient levels. The above illustrates that some of the metrics calculated from low-booms will exceed the ambient more readily than others. The metrics are based upon a single energy spectrum; thus, increasing the length of the data record used to calculate the spectrum will result in increasing levels in the spectrum until the boom and its aftermath diminish. For a perfect N-wave with zero ambient, the energy spectrum and all the metrics calculated from it will not change with record length if the N-wave is completely within the analysis window. Measured booms from the WSPR project included ambient noise as will the recordings for the Galveston test. Increasing the record length to compute loudness metrics may result in ever-increasing levels because the ambient energy will continually add to the energy spectrum. If the energy of the boom is large enough, like the example shown in Figure 10-5, the ambient is so far below the boom's energy that a metric will not change with increasing window size.

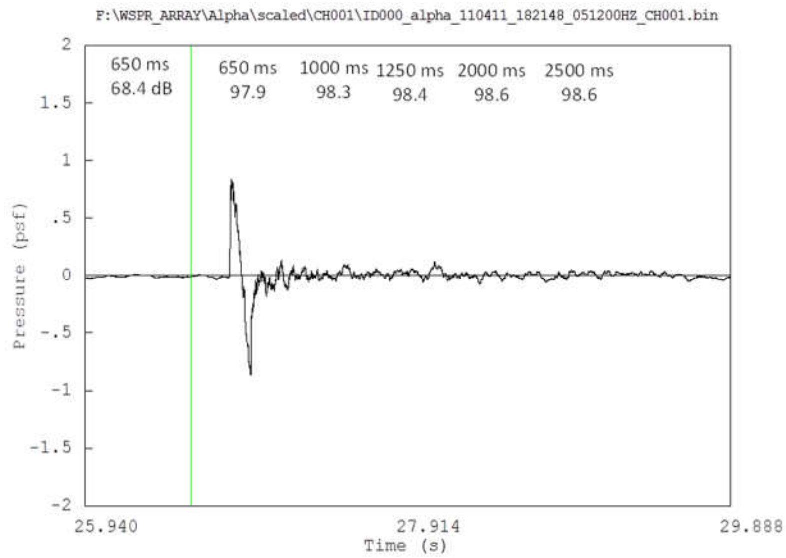

Figure 10-5 Measured Sonic Boom (psf) at Site Alpha during WSPR and computed loudness for increasing record lengths starting from the green line.

This, in effect, behaves like the ideal N wave. On the other hand, if a boom is lower in amplitude and has energy comparable to the ambient, then the only way to remove the ambient energy from the metric calculations is to subtract it from the energy spectrum before calculating the metrics. A window length of 650 ms was used during WSPR as a means to capture the entirety of the boom and minimize the interference from spurious noises (*e.g.* passing cars).

Subtraction of the ambient from the 650 ms sonic boom window band-by-band was considered for a follow up analysis of the data from WSPR and will be done for the upcoming measurements in Texas. The noise floor of the instrument will be part of the ambient spectrum if the ambient noise levels do not exceed the noise floor of the instrument measuring it.

The ambient is subtracted from the boom as follows: identify the boom in a 650 ms window and calculate its energy spectrum. Do the same for the 650 ms immediately preceding the boom's time window. If five consecutive bands do not exceed the ambient by 0.5 dB or more, then the spectrum will be discarded and the ambient will not be subtracted. For bands greater than the ambient by 0.5 dB or more, subtract the energy of the ambient level from the boom level for each of those bands. For bands that are marked as being below the ambient, their level is determined from interpolation of adjacent levels that have been corrected (unmasked) for the ambient. In the event that the highest frequency bands of the boom spectrum are no above the ambient, their levels will be determine by extrapolating the adjacent, lower bands. Figure 10-6 shows a plot of Steven's Mark VII Perceived Level calculated from the energy spectrum of the first boom with the ambient subtracted versus the metric without the ambient subtracted. Figure 10-7 shows the ambient relationship plots for the other metrics based on energy spectra.

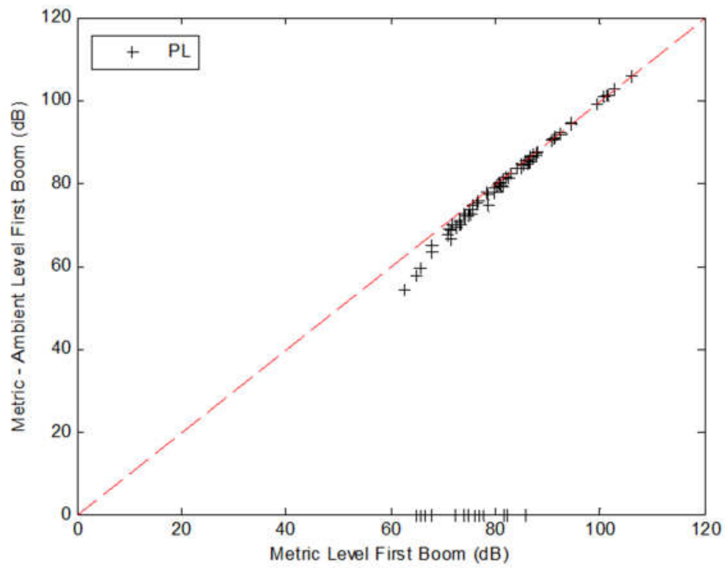

Figure 10-6. Comparison of PL with spectral subtraction of ambient and boom PL for booms recorded at Site Alpha during WSPR.

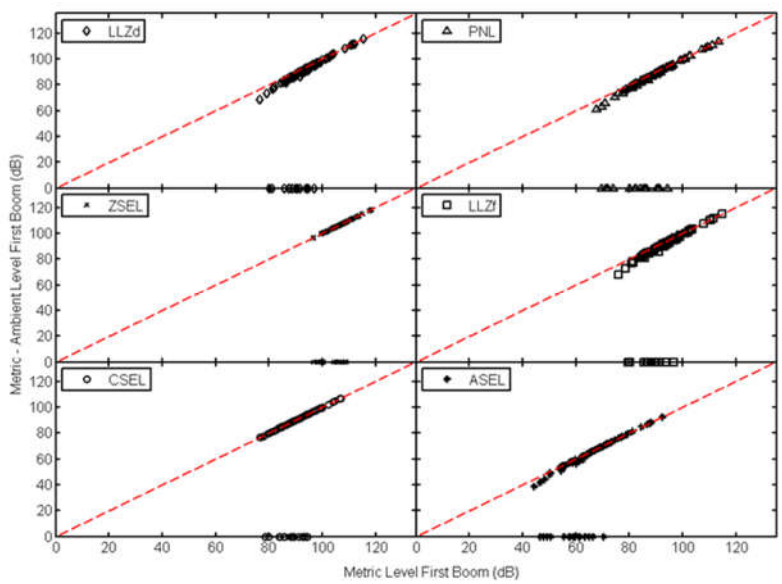

Figure 10-7 Comparison of several metrics with spectral subtraction of ambient for booms recorded at Site Alpha during WSPR.

A dashed line of slope one is plotted for reference. Booms whose energy spectrum did not exceed the ambient for five consecutive bands are plotted on the abscissa. Sonic booms whose spectrum was not sufficiently above the ambient tended to be among the bottom third of the range measured. Only booms of lower level show the effect of subtracting the ambient as evidenced by their deviation from the dashed line. This is consistent with the observation that low booms with lower PL are only marginally larger than the ambient.

Of note in Figure 10-8 is the absence of deviation from the dashed line of the CSEL and ZSEL. This suggests that if an event occurs before a boom so that the ambient cannot be subtracted across the whole spectrum, then the very high amplitudes of the lower frequencies of a boom will not be detracted by the ambient. A specific example of this behavior is presented below. The first boom (Figure 10-8) did not meet the band-by-band ambient criteria. The CSEL values for the first boom and ambient are 83.6 and 57.6 dB respectively. Figure 10-9 shows the two energy spectra for the boom and ambient.

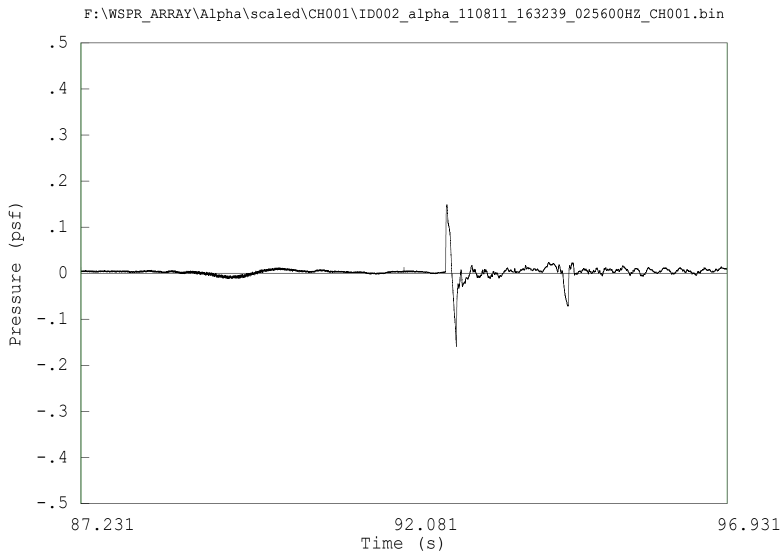

Figure 10-8 Example boom signal (psf) with CSEL ambient test failure recorded at Site Alpha during WSPR.

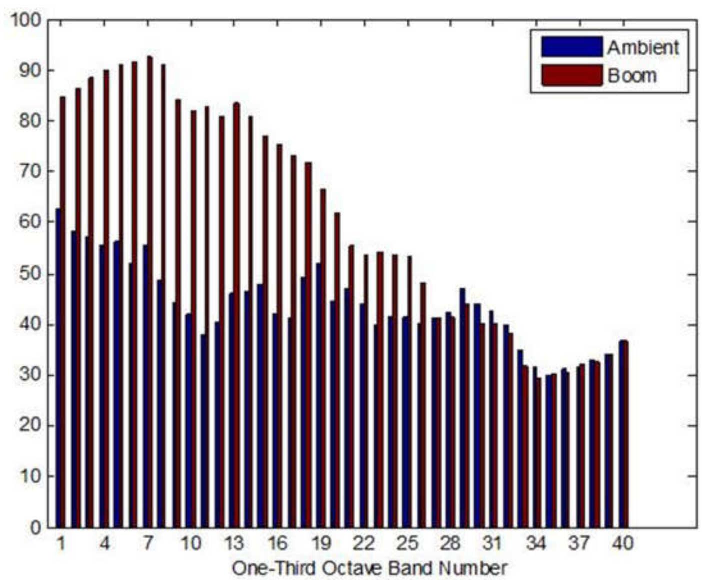

Figure 10-9 Energy spectrum for example boom and ambient.

As can be seen there is a period where 5 consecutive bands are below the ambient; thus, a spectrum with the ambient was not calculated. A car driving past the monitor caused the band-by-band criteria to not be met. The car was no longer audible just before the boom. Had the car been still making noise during the boom, its noise would have added to the spectra of the low-boom possibly allowing the band-by-band criteria to be met. Even with short duration analysis of 650 ms, the ambient noise levels can vary so as to exceed the boom levels.

When selecting a suitable analysis window size, consideration must be given to:

- The first boom and its pre-event ambient,
- The rumble afterwards, and
- The second boom.

Also of concern but not addressed here is how to calculate the metrics for various boom event elements. Prior research (Sullivan, 2010) provides a good argument for normalizing the energy spectrum by 70 ms. It was also argued that subtracting 3 dB from the spectrum was appropriate since the typical boom sounds like two bangs. Since the period of the booms is greater than the human ear's response time it is really two events; thus, the loudness of one event should be the level subtracted by 3 dB which is the same as dividing the energy by 2. Neither of these arguments is applicable to the ambient spectrum or post-boom rumble. The loudness metrics calculated in this project will use 70 ms to normalize the energy spectra and correct them by subtracting 3 dB. The SEL levels will be using the standard 1 s to normalize the energy spectra and will not be corrected by subtracting 3 dB.

Analysis of the booms recorded will be done with a modified version of the Auto Boom Finder (ABF) program (Hobbs, 2012). Modifications to the program include generating an expanded set of metrics listed in Table 10-2 and application of a more aggressive method to correct the recorded signal for the ambient. The energy spectrum of the event is corrected for the ambient in the following way:

- Any one-third octave band in the event spectrum that is not greater than 0.5 dB as compared to the same band in the ambient spectrum is marked. If the band is 0.5 dB greater than the ambient spectrum, then the band is corrected for the ambient by subtracting the ambient level energy from the band.

- For bands in the event spectrum that are marked as being too close to the ambient spectrum, the corrected levels from adjacent bands will be interpolated. This will be applied for up to four adjacent bands not having sufficient signal to noise. If more than four adjacent bands are not above the ambient, the subtraction of the ambient will not proceed. This is consistent with noise certification measurement analysis.

- If the high-frequency bands in the spectrum are at or near the ambient, a roll-off will be applied to that portion of the spectrum. A discussion of the roll-off procedure is described below.

An example of the behavior of the high frequency portion of the energy spectra involved in metric calculations is presented in Figure 10-10.

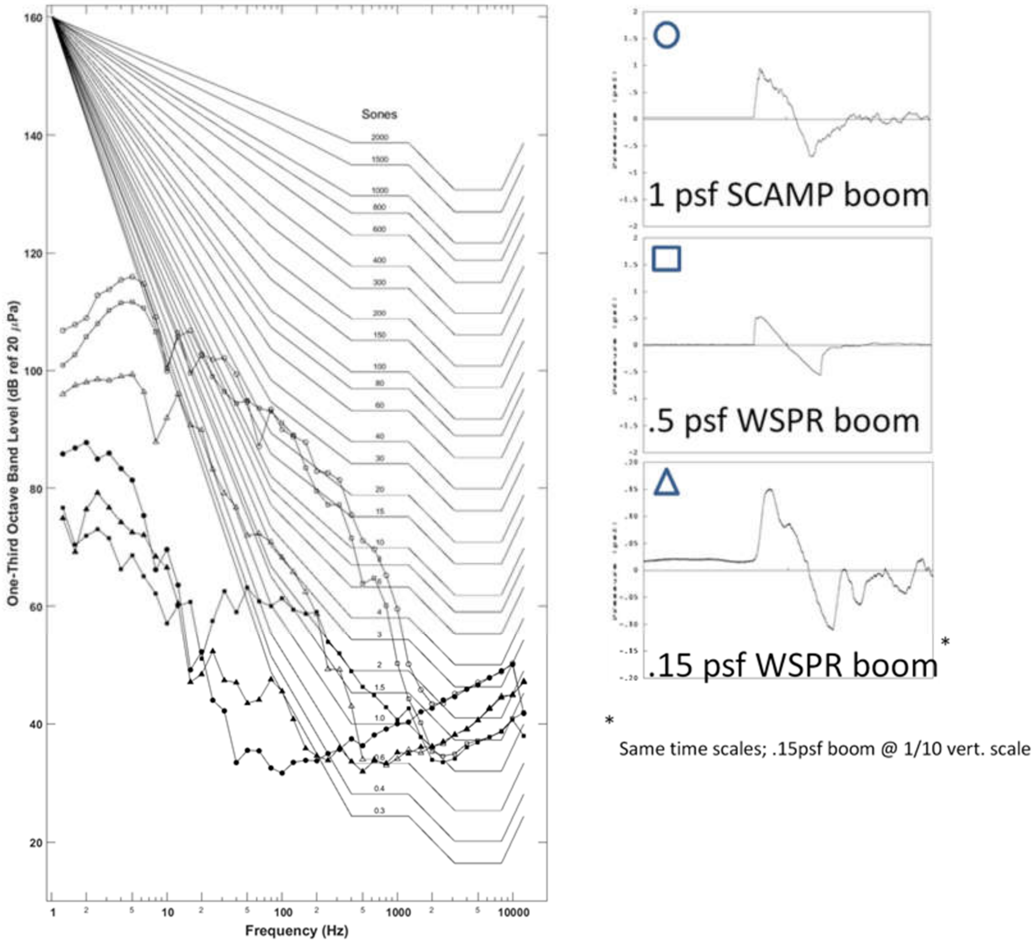

Figure 10-10 Energy of the spectra of boom events (unfilled markers) and ambient spectra (filled markers) plotted against loudness curves for calculating Stevens' Mark VII loudness.

The one-third octave bands for a 1 psf boom do not rise above the ambient beyond 2 kHz. As such, the default energy subtraction method would reject the spectrum because more than four consecutive bands are at or below the ambient. However the modified ABF program will roll off the corrected energy spectrum using the slope of the last two bands that are above the ambient and return metrics for each of the sections listed in Table 10-1. The noise metrics that are calculated are listed in Table 10-2.

Table 10-1 Delineation of Sonic Boom Recording Sections Analyzed by the Auto Boom Finder Program

Section	Description
Ambient	This section has the exposure and loudness metrics for the time just before the first boom.
1stBoom	This section has the exposure and loudness metrics for the first boom.
Between	If two booms are identified in the record, then this section has the exposure and loudness metrics between the booms.
2ndBoom	This section has the exposure and loudness metrics for the second boom.
BigTime	If the user elects to have a large amount of time analyzed, then this section has the exposure and loudness metrics of that time.
1st-Amb*	This section has the exposure and loudness metrics calculated from the spectrum of the first boom minus the ambient.
2nd-Amb*	This section has the exposure and loudness metrics calculated from the spectrum of the second boom minus the ambient.

Table 10-2 Metrics Returned by the Auto Boom Finder Program[4]

Metric	Unit	Description
PL	dB	Steven's Mark VII Perceived Level
XSEL	dB	A,B,C,D,and E-weighted Sound Exposure Level
FSEL	dB	Unweighted Sound Exposure Level
LLZf	Phons	Zwicker loudness for frontal incidence
LLZd	Phons	Zwicker loudness for diffuse incidence
PNL	dB	Kryter's Perceived Noise Level
ISBAP	dB	Indoor Sonic Boom Annoyance Predictor
MxPSF	psf	Maximum pressure
MnPSF	psf	Minimum pressure

[4] If NASA can provide a function to calculate the LCSmax of a sonic boom recorded by the field kits, then it can be considered for addition to the metric analysis.

11. Dose Response analysis plans

The survey instruments include single event, daily summary and background survey questions. This set of surveys will assess annoyance due to low boom noise as well as the participants' responses on a set of features that will include aspects such as demographic variables, their attitudes towards noise in general, their attitudes towards the noise source, their individual level of noise sensitivity, and their perceived ability to habituate.

The responses to the survey questions will provide data to assist in interpreting the results of the dose-response models. The outcomes from this F-18 low boom community noise test will provide guidance for the development of the future LBFD field tests by evaluating methods for noise measurement, dose estimation techniques, and the validation of survey methods. Analysis of the data gathered will provide understanding of the association of various noise metrics with the annoyance response. Statistical tools will be developed to evaluate the responses from these subjective response assessment instruments. The processes developed will include statistical analysis to identify underlying relationships and contributing factors. A dose-response model will be developed if this approach is supported by the data gathered.

11.1 Subjective-Objective Data Correlation

Noise metrics can be correlated with the annoyance response data, affording the identification of measures that optimize the prediction of annoyance for a given type of noise impact. In order to analyze the data, a mixed effects linear model will be implemented using SAS® Statistical Analysis software. The analysis will include statistical estimation and analysis of the results as well as correlations of the noise metrics with the subjective responses.

11.2 Statistical Analysis

The statistical analysis will evaluate the subjective response variables to identify relevant factors and correlate the subjective findings with the objective noise metrics. Noise measurements will be made in the surrounding community during the period of the survey administration. The analysis will focus on the following fundamental design concepts: Single Event Analysis, Cumulative Daily Analysis and Development of a Dose-Response Model as described below.

11.3 Single Event Analysis

This analysis allows for the assessment of subjective response as a function of noise level presented at different times throughout the test design. Comparisons can be made within responses from an individual participant (same person, different time, same/different levels), as well as between participants across the presentation variables (level, time of day). The single event analysis will afford a metric assessment that can be utilized in correlating human response to a single event certification metric, and to provide single event data for future consideration of community noise impact.

11.4 Cumulative Daily Analysis

This analysis affords the assessment of the participants rating of the overall day to correlate with the cumulative noise dose. The cumulative daily analysis assesses the current community noise impact metric. Comparisons can be made within responses from an individual participant as well as between participants across the presentation variables.

11.5 Development of a Dose-Response Model

An Exploratory Data Analysis (EDA) will be conducted prior to implementing the analysis of variance (ANOVA) or analysis of covariance (ANCOVA) model to analyze the data. The model is described above in Section 5.4.

The EDA approach will be used to evaluate the appropriateness of including the multiple different covariates in the analysis, because a covariate should be included only if it has a significant relationship with the response. The EDA approach will investigate which variables explain a significant portion of the variability in the response. The main predictor variables will be the characteristics of the different noise environment (due to different geographic locations). The analysis will include as many interactions as appropriate dictated by the survey response data that is obtained.

The data will determine the components of the dose-response model of the annoyance. The annoyance response will be a function of non-noise co-variables, noise effects, and random effects, as outlined above. The Background survey solicits information that is evaluated as potential co-variables. The single event and daily summary annoyance responses are related to noise levels. Analysis can assess responses between individuals and can also analyze responses from the same individual at different times. The predictive models can be linear or nonlinear based on the data obtained.

12. QSF-18 Go/No-go

A Go/No-Go decision will be made by the NASA Principal Investigator prior to each day's testing and prior to each flight. This section leverages the criteria established for the WSPR 2011 Go/No-Go decision and outlines adaptations specifically for the Galveston test. Some of the specific criteria are still being evaluated[5] and will ultimately depend on the final SBUDAS sites.

A multitude of considerations factor into the Go/No-Go decision making process. These considerations are itemized below and organized by "Day Before" and "Day of Flight". Following the considerations discussion are the Go/No-Go criteria.

12.1 Day Before Go/No-Go Considerations:

Meteorological Conditions:

- Reliability of the weather forecast affects the uncertainty of the daily dose. This should be taken into account when making decisions regarding the PLdB delivery and associated sonic boom waypoints.
- Potential forecast for meteorological changes during the day, including changes in atmospheric stability, incoming weather fronts, and projected changes in temperature and humidity.
- Desired footprint PLdB delivery
    - Influences selection of which daily flight card to use
    - Influences timing of specific flight schedule
    - Possibly affects decisions on number of aircraft airborne simultaneously
- Under all forecast conditions (considering the projected uncertainty) and for all selected waypoints the team should avoid placing high overpressure or focused booms on land.
- Influence of humidity on PLdB dose delivery

The analysis tasks which need to be completed prior to the Galveston test include:

- Incorporate Burgers solution into waypoint planning process
- Obtain the published uncertainty assessment for weather forecasting model (if available) and determine PLdB uncertainty values given projected Galveston November meteorology.
- Obtain some past Galveston November forecasts and compare with actual data. Determine what weather trends influence uncertainty. Develop uncertainty as function of meteorological conditions so that predicted footprints including PLdB have companion uncertainty for flight planning.

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[5] Additional tasks are being added to the project scope and funded. As results become available we will update the Go/No-Go criteria accordingly.

- Assessment of Meteorology on Dive Location identification for suitable footprint placement. This is to include consideration of multiple waypoints for adjustment of the low boom portion of the footprint across the target community with due consideration of the placement of focal edges. Additionally the effects of relative humidity and wind direction are to be taken into account.
- Investigation of PCBoom Burgers best practices for the dive maneuver to improve dose quantification including possible use of F18 CFD for signature calculations

• Verify uncertainty by developing meteorological variations using Galveston historical data including variation during the day (AM to PM over the anticipated flight times) and variation from day to day variability.

12.2 Day of Flight Considerations

If there is a "significant" change in actual meteorological conditions from forecasting conditions the Go/No-Go decision needs to be reevaluated and the team should be prepared to recompute appropriate dive way-points using updated weather forecasts. Some of the pre-test analysis will attempt to quantify "significant."

Some of the technical areas to be explored prior to the Galveston test include:

- Examining the wind profile in more detail based on the Volpe 10-year Galveston meteorological study
    - Identify critical altitude bands for ray trace
    - Evaluate / quantify the effect on footprints due to an increase in winds
    - Examine the influence of a twisted wind profile on the edges and shape of the focus crescent to understand upper air conditions/ trends that could potentially result in the placement of focus and larger booms on shore.
- Humidity profile
    - Loudness impact – develop loudness sensitivity to % humidity relationships that can be applied either as rules of thumb or simple table-lookups to guide flight card and dive waypoint selection that account for uncertainty.
- Temperature profile
    - Effect on ray trace and loudness levels across the footprint – assess trends during the day as the temperature profile varies using historical data.

Onboard AC GPS / trajectory tracking: we anticipate that even in the event of the failure of the onboard aircraft trajectory tracking system that the test can occur. The effect of losing tracking data will be to utilize a nominal dive trajectory for determination of the metrics at the respondent locations. Given the prior Volpe analysis of the WSPR 2011 dives the repeatability between individual operations and the variation on the footprints was fairly benign. This analysis will be repeated for the WSPR 2011 dives loudness values at selected locations throughout the footprint to quantify the PL uncertainty. The influence on the day of flight planning will be to apply that uncertainty to selection of the flight cards and way-points if it is known a priori that the aircraft GPS recording system is not operational.

12.3 Go / No-Go Criteria

Flights will not occur in the event of the following:

1. Aircraft readiness or safety issues are not met, as determined by NASA
2. Weather
    a. Precipitation
    b. Lightning. NASA's rules regarding lightning safety for personnel will be followed.
    c. Meteorological front within or passing through the airspace.
    d. Upper air profile F-18 dive footprint delivery conditions not met.

3. Communication system failure
    a. LMR and backup systems inoperable
    b. F-18 aircraft communications inoperable
4. Instrumentation failure
    a. Failure of flight instrumentation such that position and orientation information cannot be obtained or the aircraft cannot reliably perform the low-boom dive maneuver
    b. All acoustic measurement field kits inoperative. At least one monitor must be operational; see section 12.4 below.
    c. Failure to obtain initial (pre-flight) upper air data
    d. Verizon wireless outage in the test community area evidenced by the Host Station not being able to connect with an acceptable number of SBUDAS noise monitors as defined in Section 12.4 .
5. Subjective Data Systems
    a. Cellular system failure - widespread (Galveston vs. mainland) (see also 4d)
    b. PSU subjective survey website inaccessible

12.4 Go / No-Go criteria for field kit channels and location prioritization

For flights to proceed, at least one of the twelve noise monitors must be operating normally. As the number of operational monitors decreases, reliance on predictions and inherent uncertainty increases. In the most restrictive case (one monitor), a single measured value can be used to anchor predicted levels to the realized footprint. If less than a full complement of noise monitors is ready, certain locations should be prioritized. Three locations used for noise dose design (Scholes airport, Tiki Island, and La Marque Cemetery) are high priority. If SBUDAS units at these locations are inoperative, replacement with SPIKE units should occur if possible.

Due to the non-uniform distribution of field kits across the footprint and the spatial gradients in predicted overpressures and PL, certain locations are more critical than others. Because PL levels measured at field kit locations will be used to interpolate/extrapolate PL at other locations, the underlying shape of a predicted PL footprint can be used to guide the prioritization of monitor locations.

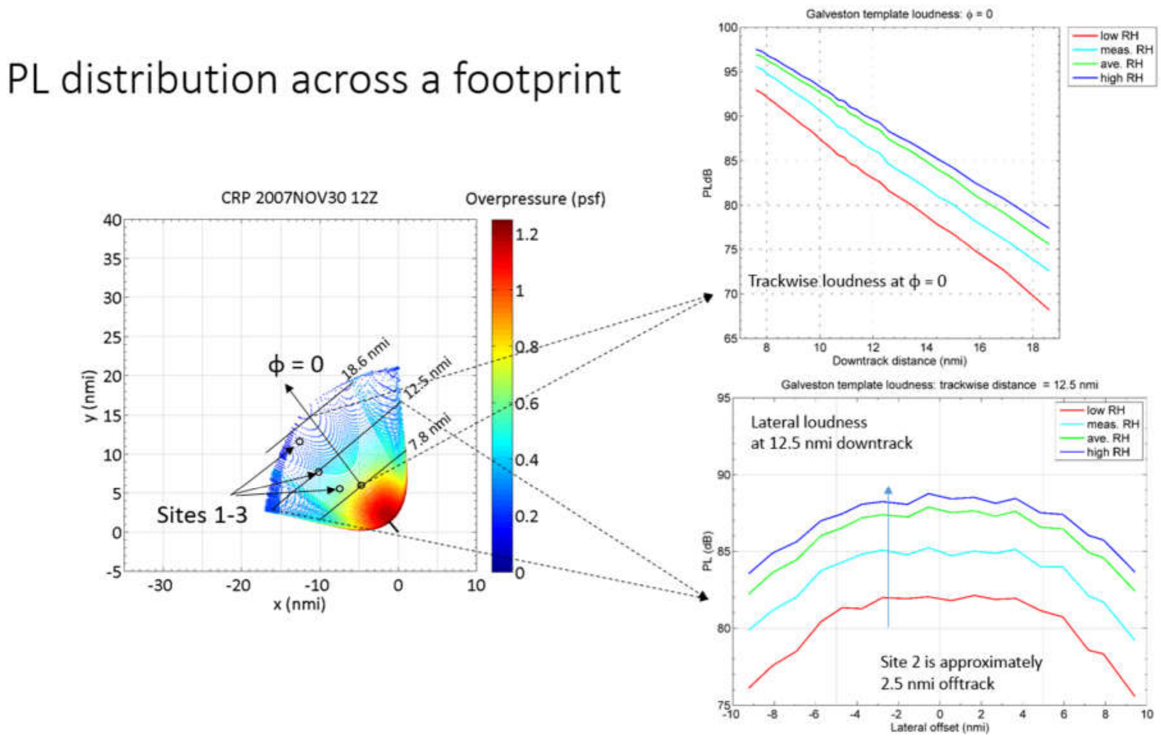

Figure 12-1 Predicted distribution of PL in trackwise and lateral directions for a nominal footprint at four different RH conditions

Considering the spatial distribution of PL across a predicted footprint in (Figure 12-1) in a broad sense it appears that trackwise distribution of PL at low azimuth angles is linear in the low-pressure portion of the footprint, whereas the lateral distribution is more like a parabola or higher-order polynomial. Successful extrapolation/interpolation in the lateral direction will therefore require a larger number of measurement points. Thus, it may be more important to ensure that sufficient lateral coverage is present while a trackwise interpolation scheme could be implemented with fewer measurement locations.

Extrapolation of polynomials introduces higher uncertainty than interpolation. Interior location field kits may therefore be less critical than those on the border of the field kit array. Furthermore, since the dive waypoint will be adjusted to place different parts of the footprint over the field kit array, different sets of high-priority locations are considered. Taking these points into consideration, the following criteria are suggested for distributions of field kits. For dive waypoints 1 and 2, the four "corners" of the field kit array (see Figure 12-2) are critical for minimizing the extent of extrapolation, and at least three of these four locations should have operational field kits. For interior locations, a slightly larger number of missing field kits may be permitted, provided they are not clustered together. To ensure that sufficient lateral and trackwise measurement resolution is achieved, at least one location in each of groups 5 and 6 should have an operational field kit, and at least two of four locations in group 7 should have an operational field kit. These location groupings are summarized in Table 12-1.

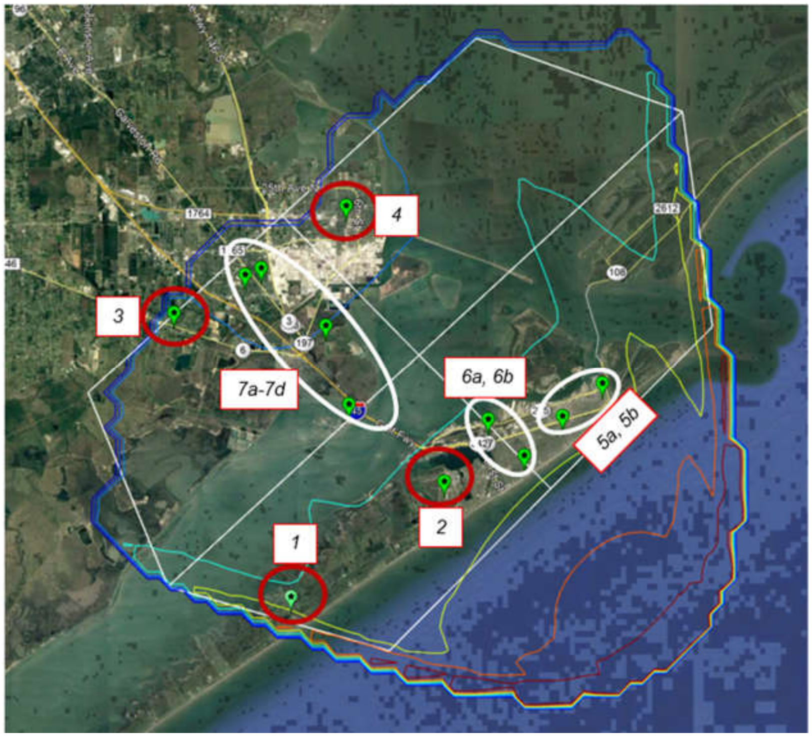

Figure 12-2. Noise monitor locations grouped by priority: dive waypoints 1 and 2. High-priority locations are at least 3 out of 4 field kits in the red circles (locations 1-4), at least 1 field kit in each of groups 5-6, and at least 2 field kits in group 7.

For dive waypoints 3 and 4, in which the down-track portion of the footprint is placed over Galveston Island, measurement locations there become more critical. Measurement locations on the mainland are also needed both to capture noise from evanescent waves and perhaps from the primary footprint if the realized extent of the footprint is greater than the predicted extent. In the Figure 12-3 below, for dive waypoints 3 and 4 at least five of the six field kits in the red circles (locations 1-6) on Galveston Island should be operational. For groups of field kits in the white circles, at least one field kit in each of groups 7 and 8 should be operational. These location groupings are summarized in Table 12-2.

Table 12-1 Prioritization of noise monitor locations for dive waypoints 1 and 2. Locations 2, 7a, and 7d are high priority sites for correlation of measurements with noise dose design.

Location	Description	Prioritization
1	Galveston Fire station #7	3 of 4 monitors operational
2*	Scholes Airport / Galveston Fire Station #4	
3	Missionary Baptist Church	
4	Texas City Fire Department #2	
5a	Kempner Park	1 of 2 monitors operational
5b	Galveston Fire Station #2	
6a	NOAA NMF	1 of 2 monitors operational
6b	56^{th} Judicial District Court	
7a*	Tiki Island Fire Station	2 of 4 monitors operational
7b	Campbell Bayou Road Intersection	
7c	UPS Customer Service Center	
7d*	La Marque Cemetery	

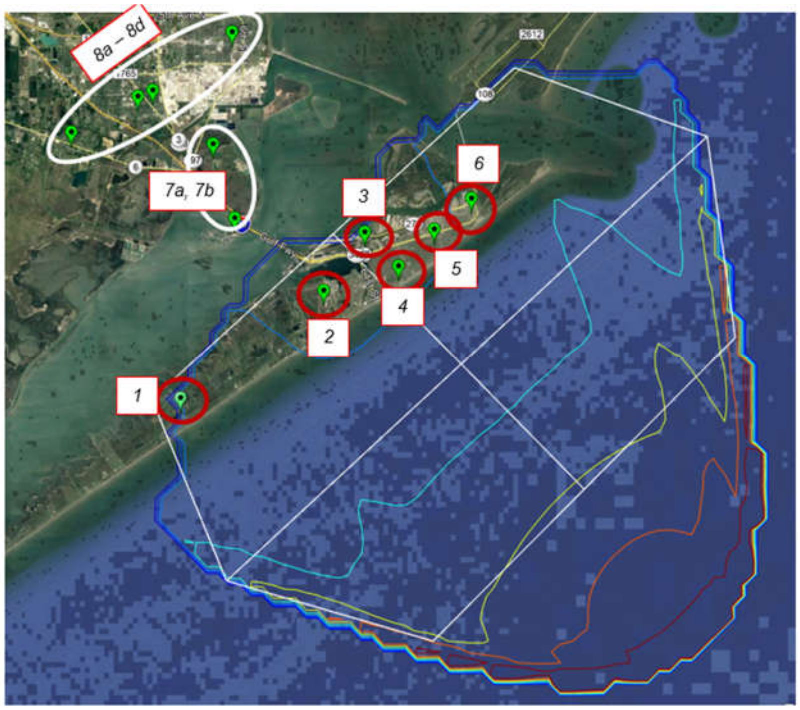

Figure 12-3. Noise monitor locations grouped by priority: dive waypoints 3 and 4. High-priority locations are all of the field kits in the red circles (locations 1-6), and at least 1 field kit in each of the white circles (groups 7-8).

Table 12-2 Prioritization of noise monitor locations for dive waypoints 3 and 4. Locations 2, 7a, and 8c are high priority sites for correlation of measurements with noise dose design.

Location	Description	Prioritization
1	Galveston Fire station #7	5 of 6 monitors operational
2*	Scholes Airport / Galveston Fire Station #4	
3	56th Judicial District Court	
4	NOAA NMF	
5	Kempner Park	
6	Galveston Fire Station #2	
7a*	Tiki Island Fire Station	1 of 2 monitors operational
7b	Campbell Bayou Road Intersection	
8a	Missionary Baptist Church	1 of 4 monitors operational
8b	UPS Customer Service Center	
8c*	La Marque Cemetery	
8d	Texas City Fire Department #2	

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E. Supplemental Meteorological Analysis and Go/No-Go Criteria

The following pages provide Appendix E. This appendix file is provided separately from the main body of the report.

Memorandum

U.S. Department

of Transportation

Subject:	QSF-18: Supplemental Meteorological Analysis and Go/No-Go criteria	Date:	06 May 2019
From:	Robert Downs and Juliet Page, Volpe V-324		*Project: VPH9*
To:	Jonathan Rathsam, NASA and Robert Hunte, APS		

As part of QSF-18 planning preparations, a number of investigations were made into how meteorological effects (chiefly wind and relative humidity) could affect dive waypoint placement and ground thump loudness. Resulting from that work, go/no-go criteria were developed to identify conditions that would lead to dive footprints not well suited to a community response test. This document summarizes supplemental analyses of meteorological effects on dive footprint modeling and placement. It also documents the data source and investigation of off shore oil rig locations relative to the sonic boom and focal zone placement.

Assessment of meteorological conditions on dive location

Background: moving dive waypoint to target overpressure level at design point

A key facet of the QSF-18 noise dose design and test execution was that levels would be varied at specific locations by changing the waypoint of the low-boom dive maneuver, and in effect, moving the footprint relative to the geographic area where the participants were located. Using a template atmospheric profile, nominal waypoints were determined by matching modeled overpressure at a noise dose design site (Scholes Airport on Galveston Island) with specific levels. Figure 1 illustrates how dive waypoints are shifted progressively away from the coastline so that Galveston Island is moved to increasing downtrack distances to lower pressure portions of the modeled footprint. In Figure 1 the nominal footprint overpressure values are plotted in color and the white quadrilateral is the targeted recruitment area. Based on that set of template conditions, the difference in position along a nominal bearing between dive waypoints 1 and 4 is approximately 10 nmi. It is known, however, that changes in atmospheric conditions can vary the size and shape of the footprint as well as overpressure and loudness levels. Thus, while the dive waypoint was shifted deliberately based on target overpressures, variability in atmospheric conditions alters the exact location of any set of waypoints for a specific atmospheric condition.

Figure 1. Illustration of moving dive waypoints to set overpressure levels on Galveston Island

Wind direction effects on dive footprint

Although many factors influence propagation and thus, boom footprints, the two most prominent contributors to ground boom variability are winds and relative humidity. Atmospheric turbulence is also known to have a strong effect on boom levels but measurements or other information on atmospheric turbulence were outside the scope of QSF-18 tests and the waypoint planning process. The emphasis of the present analysis is on how atmospheric wind profiles affect distribution of overpressure footprints, and in the following section, how relative humidity influences modeled loudness via molecular relaxation.

Wind speed and direction across the range of altitudes through which rays propagate, play a role in how ray paths develop. To investigate the effects of wind profiles on boom footprints, a measured atmospheric profile was chosen from a historical balloon dataset. The specific profile was selected based on having consistent wind direction above 10,000 ft with speeds large enough to substantially affect the footprint. For this investigation, the measured wind profile was rotated through different angles and PCBoom was used to model boom footprints with the modified atmosphere files. To begin, the entire wind profile was rotated such that the prevailing wind at dive altitude was a headwind. This rotated wind profile is shown in Figure 2, in which wind vectors are color-coded based on altitude range. In the lowest altitude band (less than 5,000 ft), the wind is largely a crosswind.

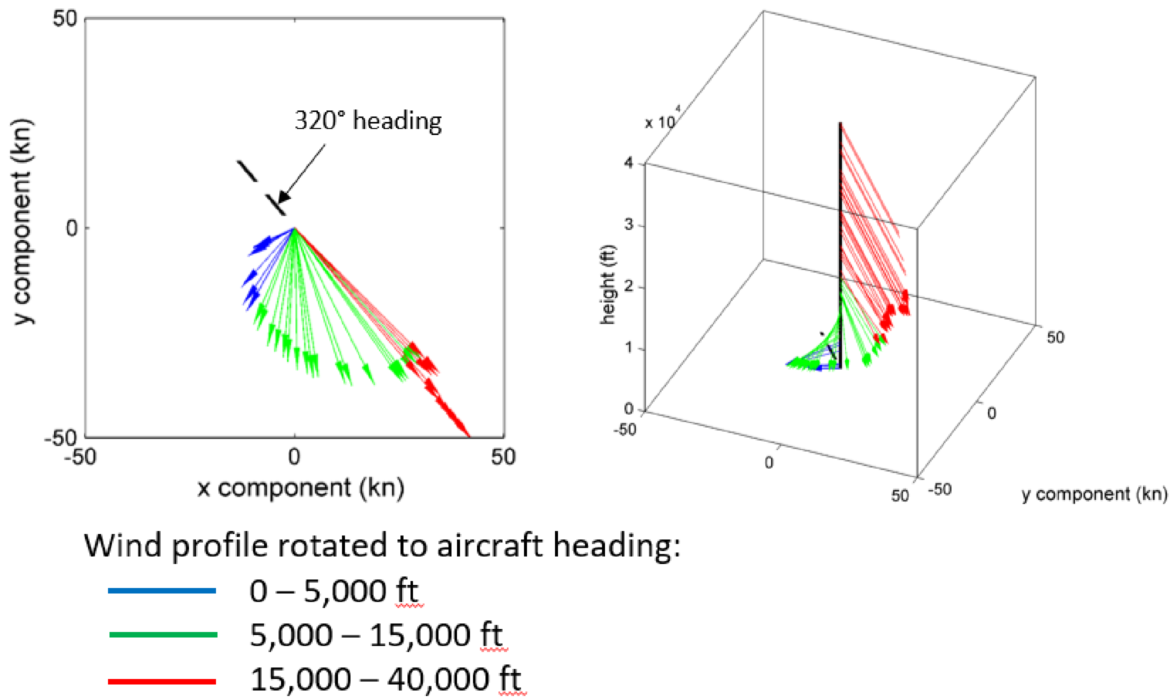

Figure 2. An example wind profile from historical balloon data, with wind direction rotated to be a headwind at aircraft altitude

From this orientation, the full wind profile was rotated through increments of 90 degrees to investigate how headwinds, tailwinds, and crosswinds at dive altitudes affect the formation of the footprints. In addition, a case was modeled in which the wind speed in the atmospheric profile was set to zero at all altitudes. The resulting footprints from these five wind profiles are shown in Figure 3. In the no-wind case, the footprint appears symmetric about the undertrack line. For the predominantly crosswind cases, the footprints are skewed towards the direction from which the wind is blowing. For the tailwind case, the result of having wind aligned with the aircraft heading, is to significantly increase the propagation distances and stretch the footprint over a larger geographic area. Conversely, the headwind case illustrates that the footprint covers a much smaller area. In addition to footprint shape, overpressures within the footprints are altered by winds. For the tailwind case, carpet overpressure at cutoff for the last isopemp is 0.04 psf, compared with 0.31 psf in the headwind case. The question of how much headwind or crosswind leads to footprints poorly suited to low-boom community response tests is addressed in the second half of this document.

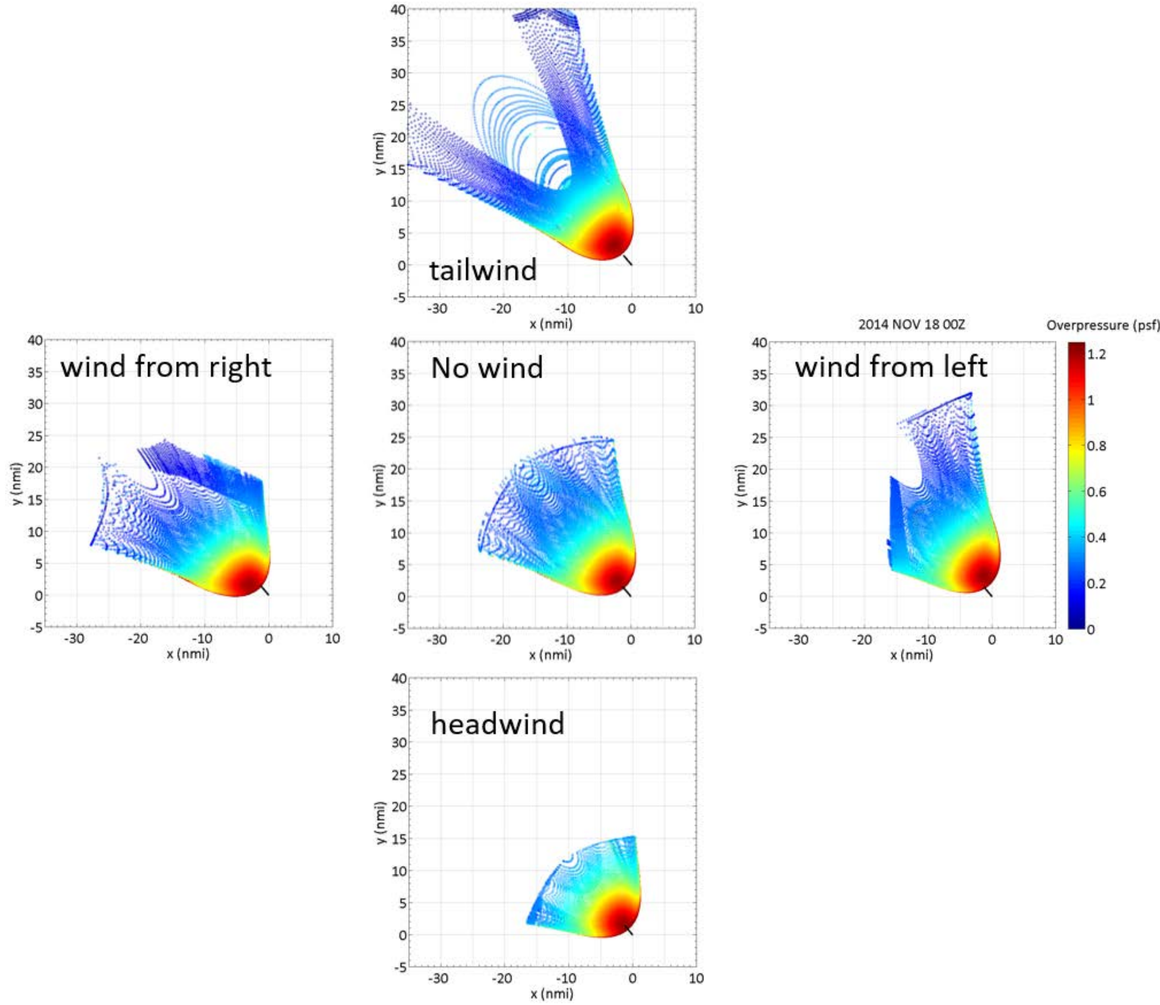

Figure 3. Modeled footprints in which the wind profile from Figure 2 was rotated in 90-degree increments. Plot labels refer to wind direction relative to aircraft heading at flight altitude

Day-to-day and hour-to-hour variability from pre-test planning

As discussed in the preceding section, wind direction and magnitude affect overpressure footprints, and thus, a sufficiently large change in atmospheric conditions (wind and temperature) can alter placement of a design waypoint by a non-negligible distance. To investigate the effect of constantly changing atmospheric conditions on waypoint placement, a set of upper air forecast data from a week in late October was used to model footprint variation due to atmospheric conditions over the course of test-day periods from 14Z to 00Z (0900 – 1900 local in Galveston, TX). The regions enclosing modeled footprints are collected in Figure 4 and grouped by day. Each subgraphic shows footprint boundaries across the test day periods, anchored to a common dive waypoint. Different trends are observed in these graphics. For 21 October (bottom left), the region covered by the footprint steadily expands over the course of the test-day period. A similar trend is apparent in the results modeled using 19 October and 22 October data, though not as consistently as in the 21 October data. Footprints modeled using forecast data for other three days, however, do not follow this trend. The set of footprint boundaries in the upper right (20 October) show that in general, the region covered by the footprint decreases in size over the course of the test-day period.

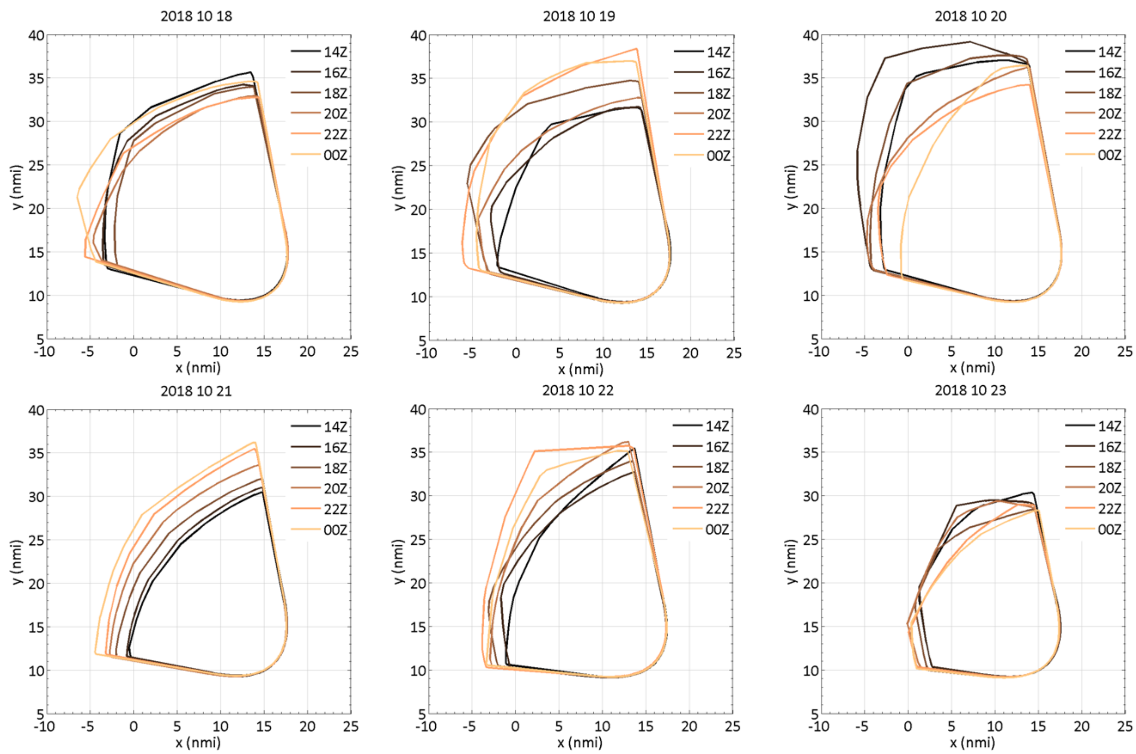

Figure 4. Comparison of modeled footprint across typical test day (14Z to 00Z), for six consecutive days of forecast data

To put these results in the context of dive waypoint placement, each of the footprints in Figure 4 was shifted to place them such that design overpressures coincided with Scholes airport. While atmospheric conditions can change the boundaries of footprint as shown in Figure 4, overpressure inside the footprint boundaries is the quantity used to set dive waypoint placement. For waypoint three, footprints were shifted such that overpressure at Scholes airport was modeled to be 0.20 psf. Comparing the shift in waypoint 3 locations across the course of test-day periods as in Figure 5, it is observed that waypoint three can move up to 4 nmi in a given period, and can move in either the uptrack or downtrack direction.

While there does not appear to be a consistent time-of-day trend, the trends observed for each day take place over periods of several hours. That is, it may be reasonable to assume that absent a significant weather event, variation in waypoint placement over an hour or two is smaller than what is expected over the course of a test-day period. This supports the development of a single set of waypoints for a given flight with multiple F-18 low boom dive events.

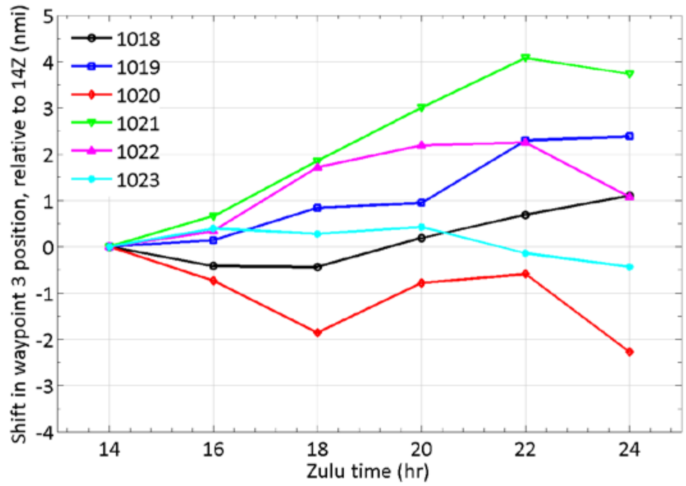

Figure 5. Change in modeled dive waypoint three position with flight time

Relative humidity effects on loudness in low-overpressure portion of carpet

In addition to overpressure, the perceived level of loudness (PL) is an important metric for QSF-18 tests. Calculation of PL incorporates the effects of shock rise times, which are sensitive to water content in the atmosphere via molecular relaxation. In short, propagation though air with a high molar concentration of water vapor results in a steeper pressure rise (i.e. shorter rise time), which has a higher perceived level of loudness. Hot, humid conditions favor high PL whereas propagation through low humidity conditions results in longer rise times and lower PL. This effect and the extent to which conditions in the Galveston area could be expected to drive PL were investigated as part of pre-test modeling activities.

The Burgers equation propagation module PCBurg was used in those investigations. PCBurg includes an option to specify a constant relative humidity value across an atmospheric profile. While that could potentially be used to bracket a range of PL or to assert a nominal value of humidity if an atmospheric profile did not include relative humidity data, the approach taken was to examine a large set of historical balloon data to estimate an expected range of relative humidity for the month of November. From that set of atmospheric profiles, the average relative humidity profile was calculated along with standard deviations at each altitude. The mean value plus or minus one standard deviation was taken as high / low humidity conditions respectively, and together with the measured template atmospheric profile this set of four profiles was used for investigations of relative humidity on modeled loudness and dive waypoint placement. The four relative humidity profiles are plotted in Figure 6.

For the four dive waypoints illustrated in Figure 1, PCburg was used to model PL at three noise dose design sites (Scholes Airport on Galveston Island, Tiki Island, and La Marque cemetery on the mainland). The results are organized by site in Table 1, such that relative humidity effects on PL can be discerned by reading across rows of the table. The difference is more pronounced in areas farther downtrack due to the longer propagation paths, where the modeled difference in PL between low and high humidity conditions is greater than 7 dB. In addition to site-specific loudness modeling, a more general set of calculations was completed at several undertrack points to better understand downtrack variation in PL. For the four relative humidity conditions considered, PL profiles in the downtrack direction are plotted in Figure 7.

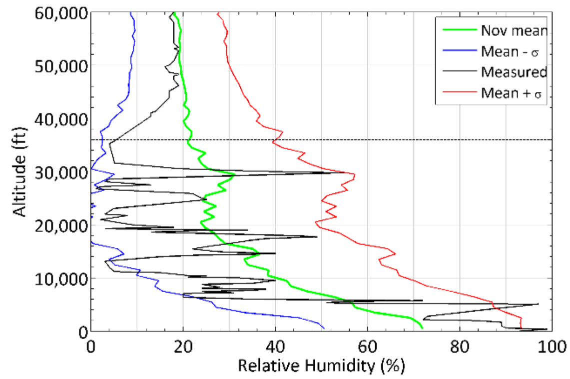

Figure 6. Relative humidity variability based on historical weather balloon data, compared with template measured profile

Table 1. Modeled effects of relative humidity and waypoint shifting on loudness metrics at three noise dose design sites. Note that Tiki Island and La Marque are outside modeled footprints for dive waypoints 3 and 4.

		PL (dB)			
Site	**Dive waypoint**	Low RH	Measured RH	Average RH	High RH
Scholes Airport	1	88.9	91.6	93.3	93.9
	2	78.2	81.5	84	85
	3	73.7	77.2	79.7	81.1
	4	67.4	71.2	73.7	75.6
Tiki Island	1	82.1	85.2	87.5	88.3
	2	70.4	74.1	76.4	78
La Marque	1	71.9	75.5	78	79.4

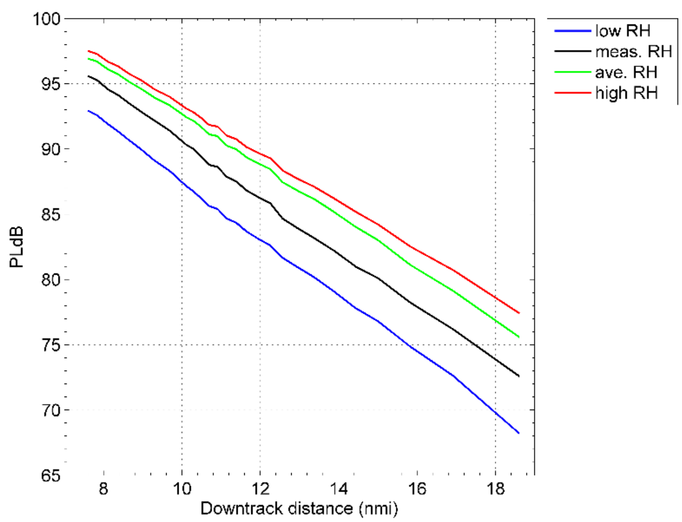

Figure 7. Modeled undertrack loudness for different relative humidity profiles

The influence of relative humidity on dive waypoint placement was also investigated. The waypoint planning procedure was based on matching design overpressure rather than PL due to the computational demands of modeling an entire PL footprint with standard PCBurg. PL modeling using forecast atmospheric data was, however, included as part of a waypoint planning using the sites listed in Table 1. Thus, PL could be used to inform decisions on dive waypoints. To show how relative humidity could affect waypoint placement based on PL, a notional level of 78 dB was considered. Using the data in Figure 7, a shift in dive waypoint needed to maintain that level was calculated at each condition and the results are listed in Table 2. Relative to the low humidity condition, an uptrack shift of 4 nmi would be needed to deliver the same loudness at a fixed location for the high relative humidity condition.

As described previously, relative humidity and temperature are driving factors in molecular relaxation. Furthermore, maximum overpressure (which is affected by wind and temperature) also influences loudness. While consistently high relative humidity across the propagation path can be used as an indicator for conditions in which high loudness can be expected, it is important to consider these other quantities, where available.

Relative humidity profile	Relative waypoint shift for PL = 78 dB at design point
Low RH profile	0.0 nmi
Measured template RH profile	1.6 nmi
Average November RH profile	3.1 nmi
High RH profile	4.0 nmi

Table 2. Comparison of waypoint shifts needed to maintain fixed PL at a design point

Refinement of go/no-go criteria

Based on these investigations of meteorological effects on dive footprint placement, conditions can be identified that are likely to produce boom footprints that are poorly suited to community response tests. The criteria considered for a suitable footprint includes a sizable region inside the footprint with overpressure less than 0.25 psf. Furthermore, in scenarios where the footprint is skewed due to high crosswind, it may not be possible to place the low pressure portion of the footprint in the intended region while keeping all higher-pressure areas offshore. By examining a large number of dive footprints modeled using measured weather data and identifying those that appeared unsuitable, common features of atmospheric profiles in those cases were identified.

The preceding investigations showed that atmospheric conditions aloft through which rays propagate affect the resulting footprint. Surface meteorological measurements will not capture all of those effects, but using them as a surrogate for a no-go check will be discussed.

Crosswind limitation

Dive footprints characterized by highly skewed shapes were found to correlate with high crosswind components in the wind profile occurring across a substantial portion of the altitude range between the dive initiation point and the ground. Specifically, if the crosswind component is greater than 100 knots for more than 30% of the altitude range the resulting dive footprint is likely to be highly asymmetric. For example, the footprint shown in Figure 8(a) was modeled with a measured atmospheric profile in which the crosswind component was greater than 100 knots for 37% of the altitude range (with a maximum of 132 knots). If airspace and other constraints allow it, changing the aircraft heading to reduce the crosswind component may be used to overcome this scenario.

Tailwind limitation

Strong headwinds can shorten propagation distances such that the dive footprint is compressed, and overpressure levels in the footprint may become too high to be used for low-boom tests. If an atmospheric profile does not have a tailwind component at any altitude, (that is, if the wind profile has a positive headwind component across the range of altitude from the dive initiation point to the ground) and if the headwind component is greater than 20 knots for more than 80% of the altitude profile, it is likely that footprint overpressures will be too high. An example of this this is shown in Figure 8(c), in which the wind profile has headwind component that is consistently positive. In that example, the undertrack overpressure at cutoff is 0.45 psf. In this scenario, high headwind at the surface appears to indicate that the atmospheric profile may not produce a suitable footprint. Specifically, surface headwinds greater than 15 knots often correlate with atmosphere profiles that fail the headwind check.

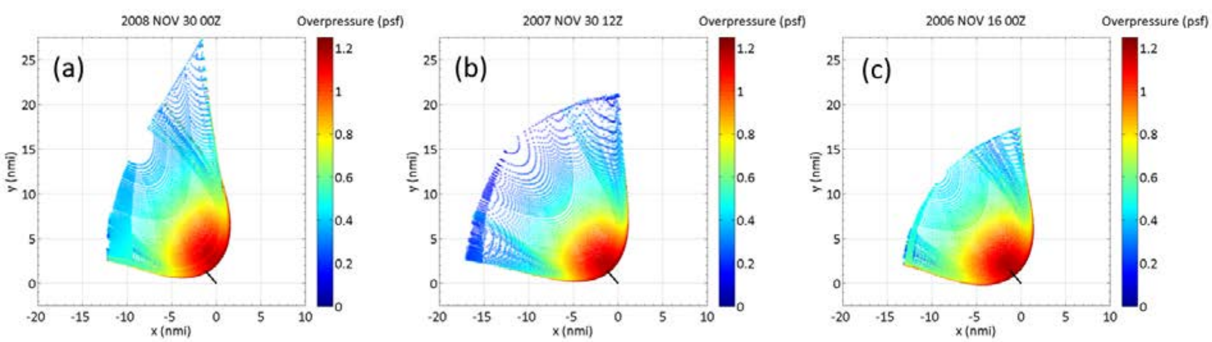

Figure 8. (a) Asymmetric footprint due to high crosswind, (b) footprint with nominal upper air profile, (c) footprint with strong headwind component in wind profile, and no tailwinds at any altitude

Oil rig locations relative to dive footprint

Proximity of oil rigs to high pressure portions of the footprint was considered in planning stages of QSF-18. The Bureau of Safety and Environmental Enforcement maintains a data center for which oil rig locations may be obtained via digital query (https://www.data.bsee.gov/). Oil rig locations relative to nominal dive footprints for waypoints 1-4 are shown in Figure 9. For dive waypoints 3-4, there are several structures that are likely to be within the footprint. Considering only regions greater than 2 psf or 5 psf in Figure 10, the affected areas comprise thin arcs near the leading edge of the dive footprint. Ultimately, the decision was made to provide offshore persons with advanced warning of sonic booms via the US Coast Guard, and no attempt was made to avoid the offshore structures.

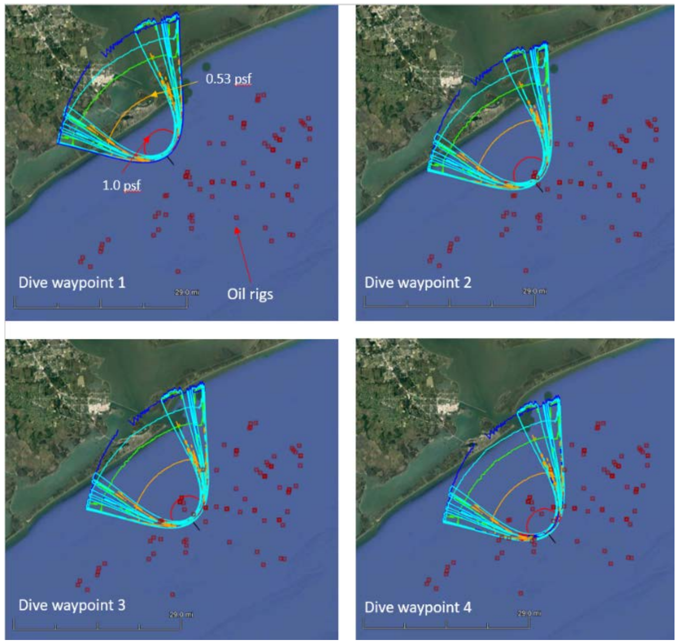

Figure 9. Modeled footprints showing proximity of oil rig locations (red squares)

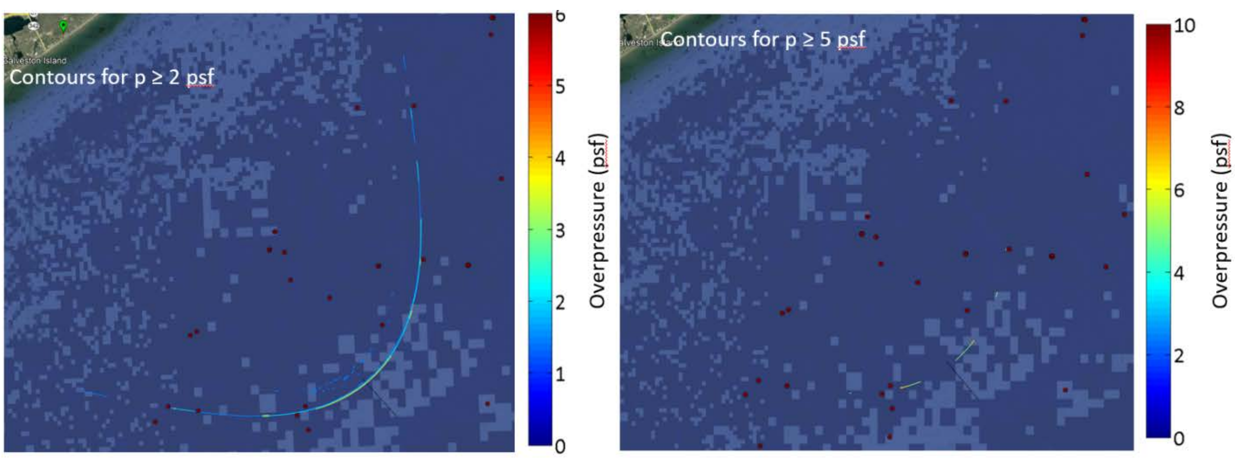

Figure 10. Contours of high overpressure in the vicinity of oil rigs (greater than 2 psf on left and greater than 5 psf on right)

F. Armstrong Flight Research Center Waveforms and Sonic boom Perception and Response Risk Reduction (WSPRRR) Test Plan

The following pages provide Appendix F. This appendix file is provided separately from the main body of the report.

NASA/CR-2017-xxxxxx

Armstrong Flight Research Center Waveforms and Sonic boom Perception and Response Risk Reduction (WSPRRR) Test Plan

Kathleen K. Hodgdon
Penn State University, Applied Research Lab

Robert P. Hunte
Applied Physical Sciences Corp.

Juliet A. Page
Volpe National Transportation Research Center

Robert A. Cowart
Gulfstream Aerospace

Domenic J. Maglieri
Eagle Aeronautics

Kevin A. Bradley
Wyle

Trent A. Gaugler
Gaugler Consulting

Prepared for
Contract NNL15AA00C
Alexandra Loubeau (Ph.D.)
Hampton, VA, January 30, 2017

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Mail Stop 148
NASA Langley Research Center
Hampton, VA 23681-2199

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Kathleen K. Hodgdon
Penn State University, Applied Research Lab

Robert P. Hunte
Applied Physical Sciences Corp.

Juliet A. Page
Volpe National Transportation Research Center

Robert A. Cowart
Gulfstream Aerospace

Domenic J. Maglieri
Eagle Aeronautics

Kevin A. Bradley
Wyle

Trent A. Gaugler
Gaugler Consulting

Prepared for
Contract NNL15AA00C
Alexandra Loubeau (Ph.D.)
Hampton, VA, January 30, 2017

Acknowledgments

Alexandra Loubeau, NASA Technical Monitor

Larry J. Cliatt, II, NASA Dryden Point of Contact

This report is available in electronic form at http://

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1 Introduction

The WSPRRR AFRC low boom response test to be conducted in spring 2017 at NASA Armstrong Flight Research Center (AFRC) on Edwards Air Force Base is designed as a risk reduction effort to evaluate methodology that will be implemented in a future low boom community response field test to be conducted in 2018 over a civilian community. A conceptual test plan has been developed for future field tests of community response to low boom noise impact in order to assess public perception of low boom signatures. The AFRC test will assess the effectiveness of a select set of methods identified in the conceptual test plan and implement changes to those methods as warranted based on the findings of the AFRC test. The high priority methods to be tested at AFRC include: participant geo-location and survey web-based technology, acoustic instrumentation cellular integration, sonic boom metric analysis and interpolation methodology.

1.1 Background

This research investigates elements related to the potential approval of supersonic flight over land for low boom aircraft. NASA has developed an F-18 flight technique for generating sonic boom noise similar to that anticipated for quiet supersonic flight. The planning and execution of human response studies will gather data to correlate human annoyance response with low level sonic boom noise. The efforts include assessment of community noise impact and methods to assess public acceptability of low boom signatures. The research being conducted at AFRC was proposed to refine and reduce risks in the WSPRRR test plan [Page *et al.*, 2016]. This research supports NASA in the collaborative planning and execution of human response studies that gather the data to correlate human perception with low level sonic boom noise.

1.2 Test Objectives

This AFRC test is to evaluate specific research methods. A primary objective is to associate boom levels measured by noise monitors and represented by noise metrics with subjective categorical responses from an on-line survey that requires participants to enable the geo-location services on their own smart phones and mobile devices. Because the participants are accustomed to hearing full level sonic booms on a routine basis, their noise ratings are not meant to represent the perception of the general public. The AFRC test is an assessment of effectiveness of methods before conducting tests in a general community.

Objectives of the sonic boom tests at AFRC using NASA personnel as participants include:

1. Test the effectiveness of the web based survey tools
2. Verify geo-location methods for subjective responses
3. Verify that we can utilize remote unattended noise monitors accessible over the internet through cellular network connectivity for the collection of acoustic data
4. Verification that desired metrics can be calculated from the acoustic measurements
5. Optimize methods for determining the noise exposure at a participant’s reported location at the time they heard the sonic boom.

The team anticipates that the combination of survey questions and GPS enabled devices will allow the team sufficient location data to determine a participant's location and correlate it with the nearest noise monitor. Methods will be explored and optimized to relate the noise measured at the noise monitor to the noise exposure dose at the participant's location.

1.3 Institutional and Federal Regulatory Compliance

The Pennsylvania State University Institutional Review Board (IRB) in the Office of Research Protections (ORP) is the IRB of record for approval of this research study. The AFRC pre-test Protocol will be shared with the NASA IRB once approved by the PSU IRB. Both PSU and NASA participate in the Collaborative Institutional Training Initiative (CITI) IRB web-based training and certification that is shared across academic institutions, government agencies, and organizations in the U.S. and around the world. All WSPRRR team members that plan to participate in the research and subsequent publications have completed the CITI training. By completing this training, all team members have complied with both the PSU and NASA IRB training requirements.

Previously the PSU IRB utilized the Protocol Review and Approval Management System (PRAMS) under which the WSPR protocol was approved. The approval of the WSPR PRAMS protocol was manually added by PSU IRB to the CITI system so that the approval of that protocol is available to NASA IRB reviewers when reviewing the WSPRRR AFRC pre-test protocol submission. This action was taken to demonstrate prior approval of the fundamental aspects of this research effort and to facilitate future approval of general community based tests.

The Paperwork Reduction Act (PRA) of 1995 requires that the US Federal Office of Management and Budget (OMB) approve each collection of information by a Federal agency before it can be implemented. The information requested is intended to ensure that agencies employ effective survey and statistical methodologies that are appropriate for the type of information that is to be collected. The OMB typically requires approval of survey protocols that are supported by federal funds and include more than 9 participants. The OMB is not required to gather protocol information if the participants are federal government employees. Since the AFRC test is to evaluate geo-location and noise instrumentation, it was determined by the WSPRRR team that it was appropriate to recruit participants from NASA personnel at AFRC.

1.4 Participant Confidentiality

Participation in this research is confidential. Only the AFRC project coordinator and investigators at the Penn State Survey Research Center will have access to the subject's identity and to information that can be associated with that identity. Location data will be used to correlate noise exposure with the location of the nearest noise monitor. In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared.

1.5 Data to be Acquired

The data to be acquired includes operational data from weather balloons, surface weather observations, predicted boom footprints from PCBoom, noise measurements and survey responses with GPS locations.

The flight tests will be dependent on weather based data. The implementation of the test will evaluate the capabilities of the noise monitors with a low boom noise input. The noise monitors should capture all sonic booms over the course of the 3 day test period. It is anticipated that all participants will complete the background survey and the daily summary of the noise perceived on that day. Ideally all participants will respond to all low boom events. Realistically we anticipate that participants may be distracted or engaged in activities that might prevent them from hearing and responding to all events Methods to determine the participants' noise dose at a given location will also be evaluated.

Data to be acquired during the WSPRRR AFRC pre-test includes:

- Flight Operations data including meteorological data
- Acoustic data capturing the noise exposure from up to 30 sonic booms
- Subjective response data from 20 to 30 participants including geo-location data

The survey questionnaire will utilize Qualtrics™, a mobile enabled web based survey software platform. The survey instruments will be mobile enabled web surveys programmed into the PSU Survey Research Center's (SRC) Qualtrics survey platform. For the subjective response geo-location data, we plan to use a feature of Qualtrics which provides the latitude and longitude position of a participant responding through the Qualtrics survey app on a GPS-enabled device. The Penn State University Survey Research Center (SRC) has developed a simple prototype survey to determine the extent to which we can determine a participant's location when they respond to a single event survey utilizing the Qualtrics application. All data collected using the mobile enabled web surveys will include time stamps and approximate geographic coordinates. This will assist in determining if respondents were in the presence of a boom when it occurred. The geographic coordinates associated with mobile devices or e-mail addresses may vary slightly by carrier and mobile device.

All subjective data sources will be merged into a single data set that will allow for detailed analysis. All personally identifiable information will be removed from the data. The data will be stripped of information such as names, addresses, e-mail address, etc., and will be linked by the case ID provided for each sample member. The subsequent data analysis will be related to the case ID number.

2 Desired Noise Exposure

The WSPRRR AFRC pre-test proposes exposing AFRC employees to three days of low-amplitude sonic booms over the course of one week, while recording their responses via structured surveys administered via self-owned GPS enabled devices. A NASA F-18 will execute a low-boom dive maneuver in order to create sonic boom N-waves with varying intensities at AFRC. The proposed low boom noise exposure design is similar to that previously tested under the WSPR program [Page *et al.*, 2014]. The noise exposure design will consist of combinations of Low (L, 0.13 psf), Medium (M, 0.33 psf) and High (H, 0.53 psf) sonic booms for 3 days within a one-week test period. The focus of this test is on location methods, and the test is not intended to be a test of low boom perception. As such there is no plan to include paired days of similar daily exposure. The design will include different daily exposures and individual boom levels in order to test the acoustic instrumentation, but a three day period is insufficient for a fully balanced noise design as was implemented in WSPR.

The daily noise exposure summarizes the single event exposures for that day. A schedule of sonic boom exposure covering a CDNL range from 48 to 57 dB is presented in Section 2.1 below. Because EAFB is an active base with frequent supersonic operations, the potential is likely that the test will be exposed to non-WSPRRR sonic boom events. The presence of non-WSPRRR boom events will raise the daily CDNL noise exposure. However, since our objectives are focused on assessing geo-location methods and testing acoustic instrumentation, this potential change in noise exposure will not have an adverse effect on our proposed test design.

2.1 Levels and Numbers of Booms

The noise design was optimized across the DNL levels that were possible using different boom combinations similar to the WSPR noise design. The design details included the day of the week, the test day, the time of day that the flight sequence was scheduled, the number of booms per flight sequence, the level of the booms in each flight sequence, the total of booms per day, the total flights per day and the associated metric level for the different boom combinations. The metrics that were included for planning were the PLDN, CDNL and DNL.

The team identified three target noise levels for the design. These levels are .13 psf, .33 psf and .53 psf for the Low, Medium and High ranges respectively. The daily noise dose is the cumulative amount of sonic boom noise that the respondent is exposed to each day. The levels are based on the data that was obtained in the NASA 2006 field test of human response to low-intensity sonic booms [Sullivan, et al., 2010] and that was tested in the previous WSPR test.

The level and number of booms were determined using the following constraints:

- Boom Targets: Lo ~ .13 psf, Med ~ .33 psf, Hi ~ .53 psf;
- Maximum of 10 booms daily
- A minimum of 20 minutes spacing between individual booms
- Booms distributed across AM and PM time periods
- Target goal of 3 distinct CDNL levels

Additional real time revisions during the field test will be made depending on the number of non-WSPRRR booms that occur on the flight test days.

The daily noise exposure was represented by tabulating the cumulative metric value from the number of each boom level distributed across the single events for each day. An example of the metric calculation is presented in Table X below.

Table 1 Single Event and Cumulative Metric Values

Single Event Metric - Basic - No Turbulence						
	PL	CSEL	ASEL	MaxPsf	MinPsf	**Number of Events**
Low	66	84	52	0.13	-0.13	**2**
Medium	83	93	68	0.33	-0.33	**4**
High	90	97	76	0.53	-0.53	**0**
Cumulative Metric Value	**39.7**	**49.9**	**24.7**			
	DNL(PL)	CDNL	DNL			

2.2 Day to Day Flight Schedule

The noise dose flight schedule was developed in such a way that it could be modified daily due to limitations with respect to weather or flight constraints. The goal is to achieve a pre-determined Daily Noise Dose through flight sequences that present specific boom combinations. The spacing between booms in a given time period is predicated on the assumption that booms from 1 or 2 aircraft may be implemented per flight sequence. The specific day or time of the boom, the boom order, and the boom spacing may change on a daily basis due to operational and environmental considerations. Field changes in noise exposure will be determined through a coordinated effort between the NASA AFRC flight coordinator and the WSPRRR co-PI that designed the noise dose exposure. The single events were distributed across each test day and across the 3 day test design as indicated flight schedule.

Table 2 Noise Design Flight Schedule

Week Day	Test Day	AM Booms// Flight	Level	PM Booms// Flight	Level	Booms/ Day	Daily Exposure	Flights/ Day	LBDM CDNL
Tues	1	(8-9)		(2-3)				3	
		2//1	2L	3//1	2M,1H				
		(10-11)							
		3//1	1L,1M,1H			8	3L,3M,2H	CDNL	52.8
Wed	2	(8-9)		(1-2)				4	
		3//1	2L,1H	3//1	3H				
		(11-12)		(3-4)					
		2//1	2H	2//1	2H	10	2L,8H	CDNL	56.7
Thurs	3	(8-9)		(12-1)				3	
		2//1	2L	2//1	2M				
		(9-10)							
		2//1	2M			6	2L,4M	CDNL	49.9
Totals						24	7L,7M, 10H		

During the experimental execution of WSPR 2011, boom levels were varied based on situational and weather conditions. For instance, if the weather was optimal for placement of Lo (.13 psf) booms and the flight sequence included Lo booms in the daily dose, the decision to place the Lo booms first was made to maximize the ideal weather conditions. If weather dictated that Lo booms were not possible that day, an attempt was made to substitute a different day without Lo booms in the design. However, with only 3 flight days for the AFRC Pre-Test, such substitutions between days may not be possible and the noise exposure may be higher than planned if weather conditions do not support the placement of Lo (.13) level booms. A summary of the noise design and the cumulative metrics for each test day is presented in Table 3 below.

Table 3 Noise Design Summary

AFRC Booms						
Test Day	Flights /Day	Booms /Day	Booms	PLDN (dB)	CDNL (dB)	DNL (dB)
3	3	6	2L,4M	39.7	49.9	24.7
1	3	8	3L,3M, 2H	44.8	52.8	30.6
2	4	10	2L,8H	49.6	56.7	35.6

2.3 Flight Operations/Boom Placement

Flight Operations are dependent on the weather conditions. We anticipate using the same approach for Flight Operations as was implemented in WSPR. A Global Positioning System (GPS)-sonde will be launched in the test vicinity to obtain current atmospheric parameters (temperature, wind speed and direction) covering the flight altitudes for the low-boom dive maneuvers. The balloon launch releases will occur about 2 hours before each scheduled F-18 takeoff in order to obtain and utilize the local atmospheric data for pre-flight planning and computation of the aircraft low boom dive maneuver waypoints. The process for determining the waypoints relies on PCBoom [Page, Plotkin & Wilmer, 2010] for propagation and prediction of ground boom footprint locations.

The flight operations information will be used to coordinate adjustments to the daily noise dose exposure as well as the proposed the F-18 waypoints in order to provide the desired amplitude sonic boom on EAFB base. Determination and adjustment of the way points on a day-to-day basis will be provided by NASA personnel. Similar to WSPR, throughout the AFRC pre-test process, care will be taken to ensure compliance with airspace requirements and to avoid placing unavoidable focused booms on populated areas.

3 Recruitment

Participants will be volunteers recruited from employees at NASA AFRC. The target is to recruit 20 -30 participants. A recruitment letter and recruitment screener were developed and are provided in Appendix A. The AFRC pre-test plan is centered on web based participant interactions. Participants will be invited to volunteer through an emailed letter, flyers or through the AFRC internal Facebook page with an invitation to respond at a website hosted by the PSU

Survey Research Center (SRC). Volunteers can contact Penn State Survey Research Center at 1-800-648-3617 or self-register at www.src.survey.psu.edu/nasa.

To be eligible, Participants must

- work at NASA Armstrong Flight Research Center
- be 18 years of age or older
- be on AFRC at least part of the day during weekday, daytime hours
- be willing to use their own smartphone or tablet with location services turned on to complete surveys

Correspondence by email will also be used as needed to ensure that the participants have received and understand instructions and survey materials and to re-confirm eligibility to participate.

4 Subjective Design

The low boom community response study is designed to measure the perception of low-level booms as rated by participants. The Penn State University SRC uses the Qualtrics™ survey application and have developed a simple prototype survey to determine the extent to which we can determine a participant's location when they respond to a survey.

The survey instruments are as follows:

- Background Survey to assess participant specific demographics and attitudes
- Single Event Survey to obtain the participant's response to each sonic boom event
- Daily Summary Survey to obtain the participants cumulative response to booms that day
- Post-test Survey to obtain feedback on ease of survey and geo-location use

AFRC test participants will be asked to complete a background survey that includes an implied informed consent, and assesses demographics and attitudes. Completion of the survey indicates the respondent's consent to participate in the research study. They will also be asked to complete a single event survey each time that they hear a sonic boom, and a daily summary survey rating the noise for the day. During the field test the respondents will receive text messages reminding them to "please remember to listen attentively" periodically throughout the day. A post-test survey will be administered to obtain participants opinions and feedback about the research methods. The data will be evaluated for effectiveness of the geo-location questions and GPS enabled devices. Further information about the survey instruments may be found in Section 4.2.

The participants are volunteer NASA employees at Armstrong Flight Research Center who work on Edwards Air Force Base and routinely hear full level sonic booms as part of their natural sound environment.

The flights planned for this field test will create a maximum of 10 booms per day during 3 days of testing over a 1 week period. The booms will be generated by 10 flights of F-18 aircraft over the test period at Edwards Air Force Base. Noise monitors will be located strategically throughout the area to record the low-level sonic boom noise exposure from the F-18 aircraft flights. The study will last for 3 days over a 1 week period. The days of the week on which the flights occur will depend on weather conditions.

4.1 Qualtrics and PSU SRC Geo-location Survey Software

We plan to use custom java script written by the Penn State Survey Research Center for use within Qualtrics which provides the latitude and longitude position of a participant responding through the Qualtrics survey on a GPS-enabled device using any web browser. In preparation for the AFRC pre-test, the Penn State University SRC has developed a simple prototype survey to determine the extent to which we can determine a participant's location when they respond to a single event survey utilizing the Qualtrics application (Figure 1).

Survey data management and geo-location will be implemented through:

- Qualtrics survey on a GPS enabled device
- PSU SRC application implemented to identify respondent's location
- Application identifies latitude and longitude of respondent
- Phone presents graphical map of location with query "Is your location correct?"
- If yes, app proceeds to boom questions
- If no, application prompts respondent to enter current addressQualtrics location application is a back up to SRC map based implementation

In compliance with IRB requirements, the respondent will need to provide informed consent to have location services enabled on their device and to allow their location to be retrieved and sent through the mobile survey. However, if the location is turned off, the respondent can input their location via a survey question. A developmental version of the geolocation feature, including map and coordinate display may be experienced at: https://pennstate.qualtrics.com/SE/?SID=SV_81cNfqxWYoBStOR.

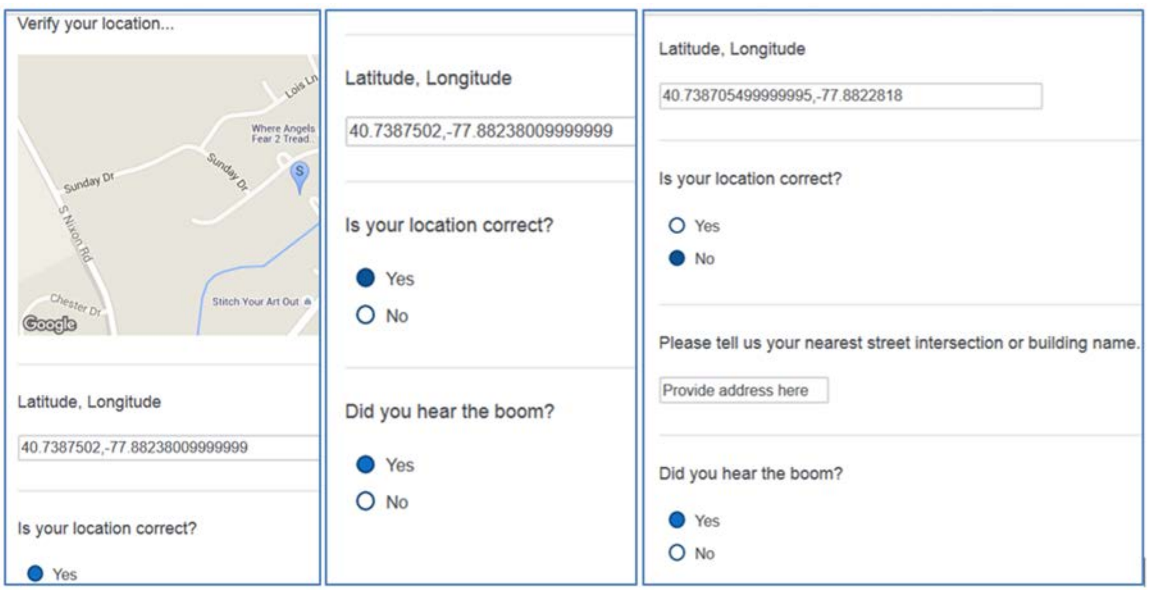


Figure 1 PSU SRC survey app interface

The data provided includes columns that show the longitude and latitude of the respondent. If recruited participants are unwilling to or have difficulty enabling location services we can still get valuable data from their survey responses, by asking them to provide the address from which they are responding. If the respondent does not have a GPS-enabled device, the software will identify an approximate location by comparing the participant's IP address to a location database. To afford greater accuracy on location, the Penn State Survey Research Center developed an additional mapping application that provides a map image of the respondents' location with a request for the respondent to validate that location as accurate.

4.2 Survey Instruments

4.2.1 Background Survey

A background survey was developed to assess the participants' demographics and attitudes towards noise and obtain characteristics of the participants. The background survey will be administered on-line prior to the field test.

Completion of the background survey will be construed as implied consent to participate in the AFRC test protocol. Participants will be informed that they will be required to use their own smart phones to respond with a phone based survey application, or their own tablets, computers or other devices for other surveys. They will be informed that they have to keep location services activated on the device used to complete the surveys. The participant location is required to associate the location where they hear each boom event with the noise measured at the location of the nearest noise monitor. The background survey is provided in Appendix D.

The survey covers the following areas:

- Social and demographic characteristics
  - Age, gender, education
  - Household size, presence of young children in household
  - Duration of employment in the AFRC area

- Attitudes related to noise
  - Attitudes about noise and ability to adapt to noise
  - Annoyance with common neighborhood noises
  - Annoyance with sonic booms
  - Other subjective reactions to sonic booms
  - Comparison of noise at AFRC with immediate prior residence

4.2.2 Single Event Survey

The Single Event survey is to be completed each time a sonic boom event is heard. The form has been modified from the survey used in WSPR to include additional questions on geo-location. Location based questions include:

- Date and time the sonic boom was noticed
- Individual's address / location at the time of the boom

- Inside or outside status at the time of the boom

The single event survey gathers information on categorical attributes that contribute to the perception of annoyance for individual boom events. These attributes include:

- Annoyance
- Loudness
- Interference with activity
- Vibration
- Rattle

Subjective response is measured using the 5 point scale with anchored end points “not at all” and “extremely”. The five point scale was implemented to afford clarity of display on smaller mobile devices such as smart phones. Appendix E provides a copy of the Single Event Survey form.

4.2.3 Daily Summary Survey

The Daily Summary Survey assesses cumulative noise perception for that day. It asks for the number of sonic booms heard during the day (including zero) and a summary rating of the respondents’ perception for booms heard during that day at both home and/or at work. The summary is requested for both locations in anticipation of circumstances where the home and work listening experience may present two distinct noise environments. This difference in noise environments could result from a variation in the boom impact across the carpet for the flight demonstrator, a variation in background noises, or differences in dwelling envelope, terrain, or other factors may create distinct listening environments.

The inclusion of home and work cumulative response affords the respondent the ability to indicate distinct perceptions if warranted. The cumulative noise exposures will be tabulated using nearest noise monitor. Participants will be asked to complete a survey once at the end of each day about their cumulative perception of the sonic booms they heard throughout the day. The Daily Summary survey includes questions on location and noise perception. The categorical attributes included on the Single Event Survey are replicated on the Daily Summary. The response ratings utilize a 5-point scale that includes “not at all,” “slightly, “moderately,” “very”, “extremely”.

In addition to categorical attributes, the Daily Summary Survey gathers data on the following:

- Summary of perception for booms heard at home and at work
  Number of sonic booms heard during the day (including zero);
-
- Whether there were any noises that might have been a sonic boom but they were not sure and, if so, what the noise(s) sounded like.

A complete listing of the Daily Summary Survey may be found in Appendix F.

4.2.4 Post-Test Survey

A post-Test Survey (Appendix G) was developed to acquire data related to ease of use for the Qualtrics Survey application and feedback on geo-location considerations. This information will be used to assess the survey effectiveness and identify any necessary survey or instruction modifications.

5 Objective Test Instrumentation

Six SBUDAS Noise Monitors will be deployed during the AFRC Pre-Test. Each of the noise monitors will be networked over a cellular VPN with a base station computer located at the AFRC Pre-Test Operations Center at AFRC. A description of the instrumentation, placement and installation details follow.

5.1 Sonic boom instrumentation description

Each SBUDAS Noise Monitor consists of the components depicted in Table 3 and shown in Figure 2.

Table 3 SBUDAS Noise Monitor Components

Component	Description
GRAS Type 41AO Environmental Microphone	The G.R.A.S. Environmental Microphone System Type 41AO (Fig. 1) is a precision microphone unit (IEC 61672) for monitoring the noise of overhead aircraft. It can withstand rain and operate over a wide range of temperatures over periods lasting from a few days to several weeks.
GRAS Type 12AQ Power Module	The G.R.A.S. 12AQ Power Module is a dual-channel power supply for preamplifiers (CCP as well as traditional) used with measurement condenser microphones.
National Instruments cRIO-9023	Embedded controller runs LabVIEW Real-Time for deterministic control, data logging, and analysis
Garmin GPS16x-HVS	Complete GPS sensor including embedded receiver and antenna
Digi TransPort WR21	Digi TransPort WR21 is a full-featured, cellular router offering the flexibility to scale from basic connectivity applications to enterprise class routing and security solutions. With its high performance architecture, Digi TransPort WR21 is designed for Wide Area Network connectivity including 2.5G/3G/4G networks.
SanDisk - Cruzer Glide 128GB USB 2.0 Flash Drive	
Solar Panel	
Solar controller	
12 Volt Battery	

Electronics Enclosure	
Sound Board	

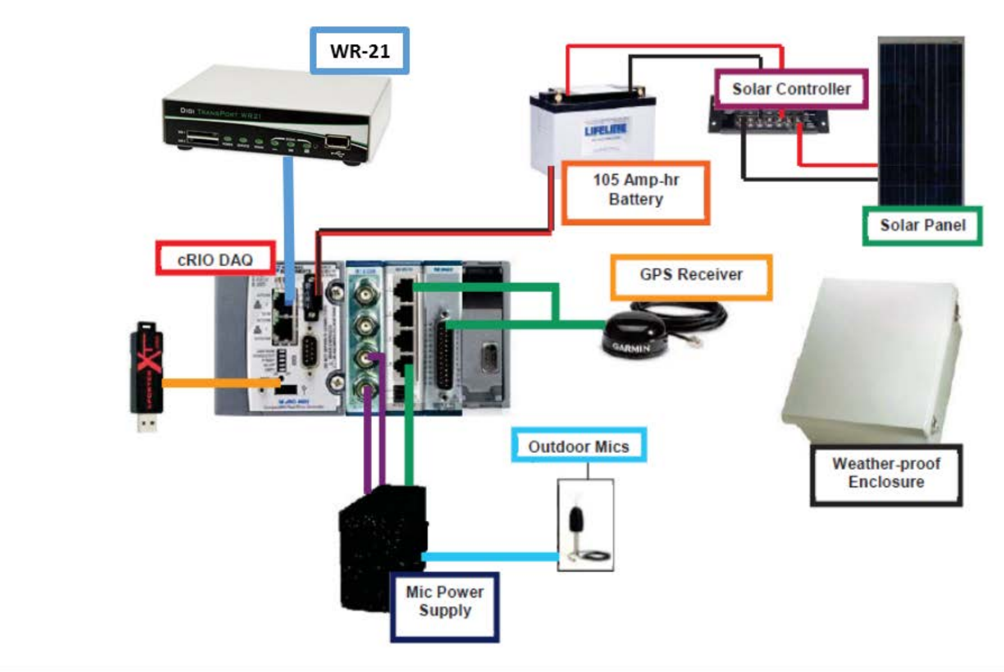


Figure 2 SBUDAS Noise Monitor Configuration

The processing associated with noise monitor is accomplished through a National Instruments Compact Reconfigurable Input Output (CRIO) device for real time data acquisition. The CRIO interfaces to a LabVIEW session running on the remote base station computer. All noise monitors will be controlled via this one LabVIEW session. Noise monitors will be deployed in the same configuration as during WSPR 2011 as shown in Figure 3.

Figure 3 SBUDAS Noise Monitor as deployed during WSPR 2011

Previous considerations concerning configuring the microphone within the SBUDAS electronics enclosure have been dismissed for the following reasons:

(1) The microphone is 11 inches in length and if mounted vertically in the electronics enclosure, flush mounted with a sound board on top it would result in the microphone being approximately 1 foot elevated above the ground level. We have estimated the impact of the incident and reflected signal and determined that measurements from a microphone at this height would be adversely impacted.
(2) We previously considered minor excavation attempts to accommodate the electronics enclosure and reduce the microphone height however these were determined to be impractical.

All SBUDAS noise monitors are being upgraded to replace the WIFI utilized during WSPR-2011 with a WR-21 Digiconnect cellular router operating on a Verizon 4G LTE network. A review of Verizon Wireless Data Coverage indicates good coverage across the lower 48 states of the United States as shown in Figure 4.

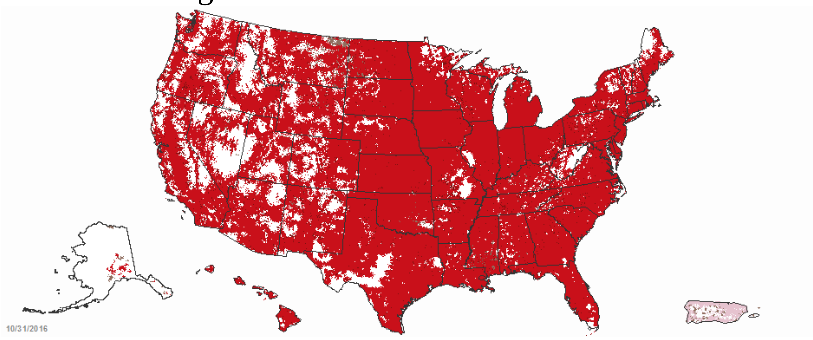


Figure 4 Verizon Wireless Data Coverage

http://vzwmap.verizonwireless.com/dotcom/coveragelocator/default.aspx?zip

This data can be independently reviewed through crowdsourced data collected through smart phone apps such as OpenSignal which are implemented to increase transparency to the wireless Industry. A detailed review of Verizon Wireless performance in the vicinity of AFRC is presented in Figure 5.

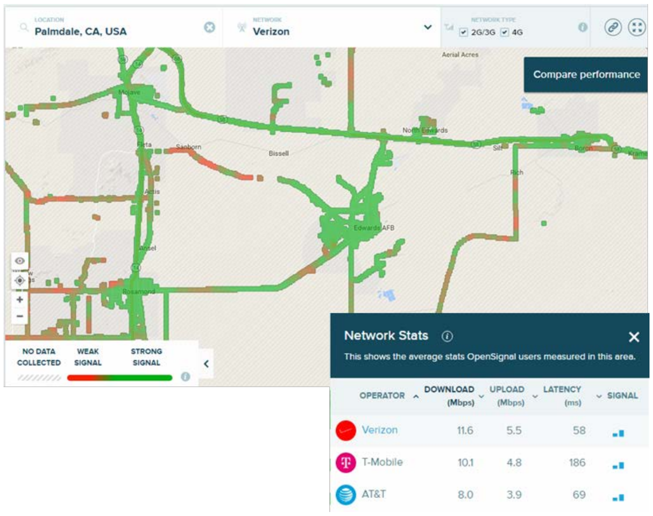


Figure 5 OpenSignal assessment of Verizon Data Coverage in the vicinity of AFRC
http://opensignal.com/networks/usa/verizon-coverage

A secure Virtual Private Network (VPN) to access each monitor over the internet from a Base Station Computer as shown in Table 4.

Table 4 VPN Configuration

WR21 IMEI	Static IP	WR21 eth0 ip	Instrument IP	Instrument gateway	Instrument DNS	Preshared Key	Instrument Desc	Instrument Name	Tunnels
359225053163739	166.239.138.140	192.168.1.1	192.168.1.100	192.168.1.1	192.168.1.1	WsPrRr	Computer	BASE	.2.1, .3.1, .4.1, .5.1, .6.1, .7.1
359225052673670	166.239.138.139	192.168.3.1	192.168.3.100	192.168.3.1	192.168.3.1	WsPrRr	NI cRIO	ALPHA	.1.1
359225052672722	166.239.138.138	192.168.4.1	192.168.4.100	192.168.4.1	192.168.4.1	WsPrRr	NI cRIO	BRAVO	.1.1
359225054963319	166.157.019.179	192.168.2.1	192.168.2.100	192.168.2.1	192.168.2.1	WsPrRr	NI cRIO	CHARLIE	.1.1
359225054963335	166.157.019.178	192.168.5.1	192.168.5.100	192.168.5.1	192.168.5.1	WsPrRr	NI cRIO	DELTA	.1.1
359225055271159	166.157.019.177	192.168.6.1	192.168.6.100	192.168.6.1	192.168.6.1	WsPrRr	NI cRIO	ECHO	.1.1
TBD	TBD	192.168.7.1	192.168.7.100	192.168.7.1	192.168.7.1	WsPrRr	NI cRIO	FOXTROT	.1.1

5.1.1 SBUDAS Testing

Initial testing of the SBUDAS network has been conducted with two SBUDAS noise monitors and a base station in a laboratory setting. As shown in Figure 6, the configuration consisted of a Virtual Private Network (VPN) established through three WR-21 modems. Two modems were each subnetted with a SBUDAS National Instruments Compact Realtime Industrial Controller (NI cRIO), with the third modem subnetted with a base station computer running the SBUDAS LabVIEW User Interface. Secure encrypted tunnels will be established from each SBUDAS Noise Monitor Subnet to the base station computer subnet using Internet Protocol Security (IPSec). We ensured that each remote SBUDAS Noise Monitor can be activated, controlled, and its data can be downloaded over this network to the base station computer.

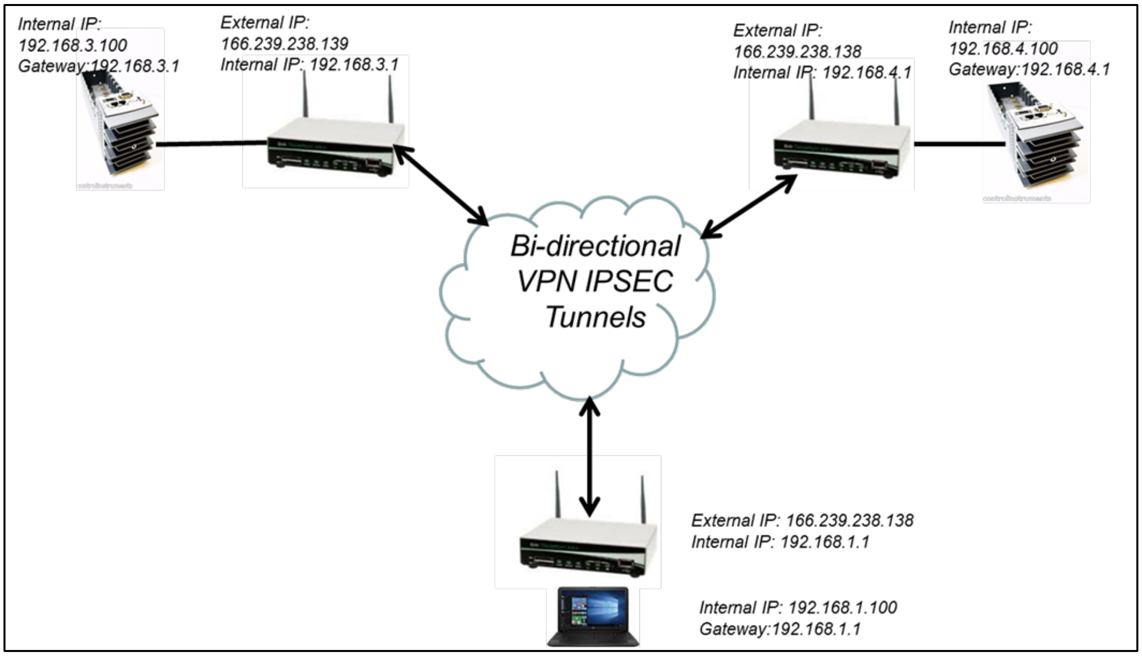


Figure 6 Initial Test configuration for SBUDAS operation over a secure VPN

Follow on testing will be conducted prior to the AFRC Pre-test with three additional noise monitors installed in remote APS facilities and controlled from the base station located at Gulfstream Aerospace in Savannah Georgia as shown in Figure 7.

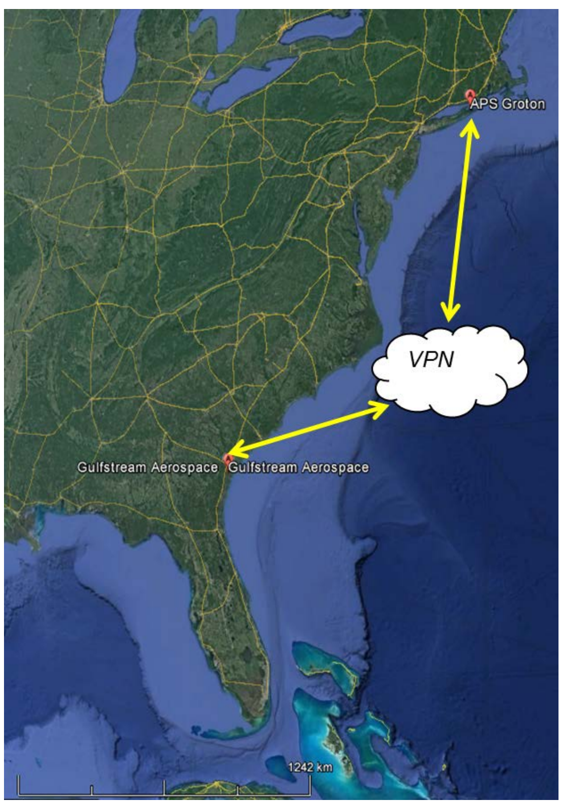


Figure 7 Follow on remote SBUDAS testing

All three of the remote SBUDAS noise monitors (Groton) will be placed in a continuous record mode utilizing the LabVIEW interface on the Base Station computer (Savannah). The engineers in Groton will utilize a Larson Davis Precision Acoustic Calibrator to inject an 114dB/251.2Hz tone to the SBUDAS microphone for 30 seconds. The Base Station Operator (Savannah) will then stop the recording and download the resultant noise file from each SBUDAS and analyze this for accuracy. All SBUDAS noise monitors to be utilized in the AFRC Pre-Test will be tested in this fashion prior to shipment and again after installation and prior to test execution.

5.2 Desired Equipment Locations

The purpose of the planned Phase 2 tests is to explore risks identified for a future QueSST Community Response Test. As shown in Figure 8, the anticipated boom footprint for a QueSST community response test will be so large that communities/participants will almost certainly be in different noise exposure regions.

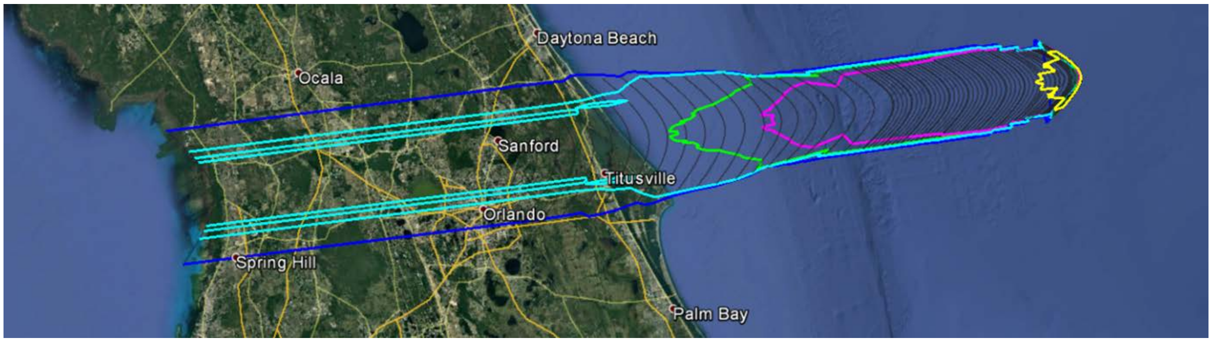


Figure 8 QueSST anticipated Low Boom footprint

Additionally, since the QueSST test plans will allow participants to have unconstrained mobility, we will need to be able to geo-locate them at their reported time of the sonic boom. The reported locations will be used to derive their noise dose from measurements made at the discrete, distributed noise monitor locations. An objective of the AFRC Pre-Test is to capture noise measurements in different locations of the Low Boom Dive footprint to support evaluation of methods for determination of participant noise exposure.

As shown in Figure 9, the low boom dive would be flown north and east of EAFB with the aircraft heading in a south westerly direction with the goal to place AFRC in the center of the footprint but far removed from the focus boom. This portion of the footprint would encompass all of AFRC resulting in a near uniform signal received at all SBUDAS noise monitors installed on AFRC property. Given that the AFRC Pre-Test is intended to explore methods rather than collect a defensible statistical community response, it is proposed that three SBUDAS noise monitors, accompanied by WSPRRR engineers be deployed on a daily basis at locations approximately 1 mile away from AFRC that capture other regions of the F-18 dive sonic boom footprint as shown in Figure 9.

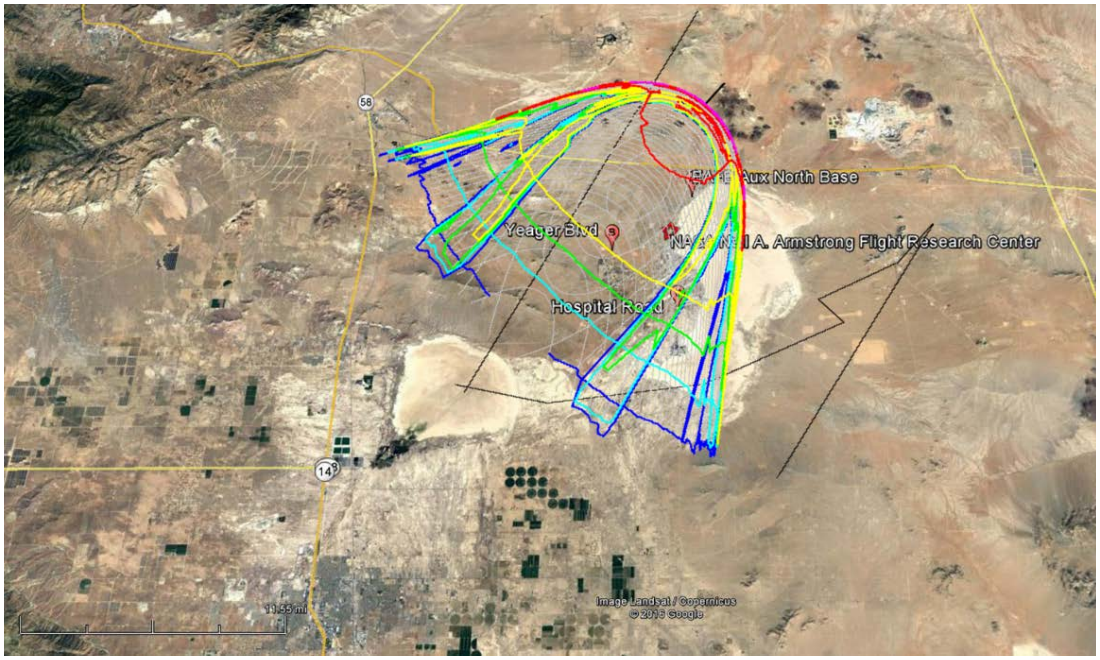


Figure 9 AFRC Pre-Test remote SBUDAS deployments

The northernmost remote monitor will be installed on the western edge of the Edwards Air Force Base Auxiliary North; the central remote monitor will be installed near the intersections of Yeager Boulevard with Forbes Avenue and Mojave Boulevard; the southernmost remote monitor will be installed near the end of the paved section of Hospital Road. The intention of this deployment is to refine our ability to determine participate noise doses by utilizing geo-location techniques, measuring a wider variation of sonic boom overpressures enabling assessment of hybrid empirical-analytical dose evaluation methods.

Figure 10 shows population centers within the AFRC facility. These centers are all within an area of less than 0.2 miles and will be subjected to a relatively uniform low boom noise dose.

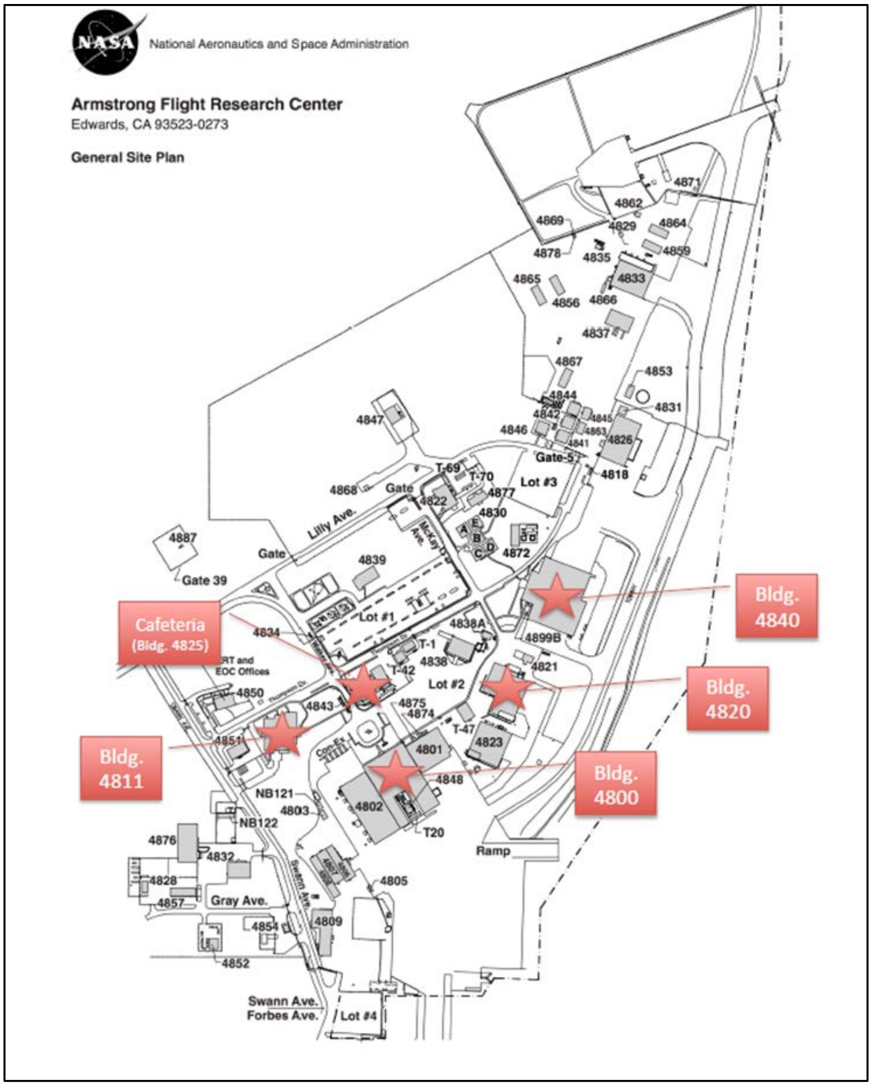


Figure 10 AFRC Heavily populated areas

It is proposed that three SBUDAS monitors be placed in the vicinity of this population center as shown in Figure 11. Two of these SBUDAS monitors would be separated by approximately 300m two noise monitors will be deployed in the vicinity of Building 4825 and Building 4840, separated by a distance of 323m; a third SBUDAS monitor is recommended to be installed at the northern most extent of AFRC at a distance of approximately 1323m from the heavily populated centers. This third noise monitor is intended to ensure that we have sufficient separation between participant responses to expand on our “geolocation of participants” evaluation; it may be accompanied by a WSPRRR engineer. This engineer will install the equipment and provide a subjective response via the web-based smartphone survey.

Figure 11 SBUDAS deployment on site AFRC

The latitude and longitude positions of the planned deployment of SBUDAS noise monitors is denoted in Table 5.

Table 5 SBUDAS deployment positions

Instrument Name	Latitude	Longitude	Description

BASE			WSPRRR Control Center
ALPHA	34°58'59.75"N	117°52'4.92"W	EAFB North Aux Base
BRAVO	34°56'18.62"N	117°56'24.31"W	Yeager Blvd
CHARLIE	34°53'24.69"N	117°52'53.62"W	Hospital Road
DELTA	34°57'49.47"N	117°53'7.09"W	AFRC North
ECHO	34°57'10.56"N	117°53'8.93"W	AFRC BLDG 4840
FOXTROT	34°57'3.15"N	117°53'19.56"W	AFRC BLDG 4825

5.3 Installation Plans / Permissions / Requirements

Permission for installation of all equipment to be installed on EAFB and AFRC property will be coordinated through NASA AFRC.

The three SBUDAS noise monitors installed on EAFB property will be deployed on a daily basis and be accompanied by WSPRRR engineers who will respond as a participant using the web-based smartphone survey. These noise monitors will not be configured with the solar panel as shown in Figure 3; instead they will consist of the low profile electronics boxes with microphones alongside on a ground board.

The three SBUDAS noise monitors installed on AFRC property will be deployed for the duration of the Pre-test.

6 Experimental Execution

6.1 AFRC Test Program Schedule

Table 6 AFRC Test Program Schedule

Dates	Activity
January 30 2017	AFRC Test Plan Submitted to NASA
January 2017	NASA / EAFB Public Affairs Coordination
January 2017	PSU IRB Submission
February 2017	PSU IRB Approval
February 2017	NASA IRB Submission
March 2017	NASA IRB Approval
April 2017	Flight Operation Plans Finalized
April 18 2017	Initiate Recruitment
May 2017	Noise Exposure Plan Reviewed by Pilots
May 1-5 2017	Ship SBUDAS to EAFB
May 9 2017	Close Subject Recruitment
May 12-14 2017	Equipment Installation
May 12 2017	SNOOPI[1] Installation @ EAFB
May 15-19 2017	AFRC Flight Test

1 Supersonic Notification Of OverPressure Instrumentation (SNOOPI), NASA Boom monitoring instrumentation, requested GFE for this test

6.2 Primary Points of Contact

Table 7 Primary Points of Contact

Name & Role	Organization	Responsibility	Email	Phone
Alexandra Loubeau **NASA PI**	NASA LaRC	1. WSPRRR Technical Monitor	a.loubeau@nasa.gov	757-864-2361
Larry Cliatt **NASA Test Coordinator**	NASA AFRC	1. AFRC Coordination 2. Flight Operations Planning	Larry.j.cliatt@nasa.gov	661-276-7617
Robert Hunte **WSPRRR Co-PI/Team Lead**	Applied Physical Sciences	1. WSPRRR Co-PI/Team Lead 2. Team Coordination 3. Objective Measurements	rhunte@aphysci.com	401-439-4552
Kathleen Hodgdon **WSPRRR Co-PI**	Penn State ARL	1. WSPRRR Co-PI 2. Compliance Protocols 3. Participant Recruitment 4. Community Outreach 5. Subjective Response measurement and analysis	Kkh2@psu.edu	814-880-3438
Juliet Page **Field Crew**	Volpe National Transportation Systems Center	1. Detailed Test Plan Development 2. Flight Test coordination 3. PCBoom footprint forecast 4. Post event boom analysis	Juliet.Page@dot.gov	410-507-0764
Matt Collmar **Field Crew**	Gulfstream Aerospace	1. SBUDAS field engineer	Matthew.Collmar@gulfstream.com	912-395-9376
Kelsey Huyghebaert **Field Crew**	Applied Physical Sciences	1. SBUDAS field engineer	Khuyghebaert@aphysci.com	860-448-3253 ext 164
Christopher Hobbs **Test Planning**	KBR Wyle	1. Post event acoustic analysis	Chris.hobbs@wyle.com	571-814-4914
Kevin Bradley **Test Planning**	KBR Wyle	1. Post event acoustic analysis	Kevin.A.Bradley@wyle.com	571-814-4914
Robbie Cowart **Field Crew**	Gulfstream Aerospace	1. Event Planning Oversight	Robbie.Cowart@gulfstream.com	912-658-9066
Domenic Maglieri **Test Planning**	Eagle Aeronautics	1. Analysis oversight	maglieri@eagle.com	757-643-7839

6.3 Pre-Test Responsibilities

Table 8 Pre-Test Responsibilities

Robert Hunte	APS	1. SBUDAS integration over cellular VPN 2. Shipment of SBUDAS noise monitors
Kathleen Hodgdon	Penn State ARL	1. IRB approval 2. Smart Phone Accessible Survey Response tool and participant geolocation 3. Recruitment and outreach coordination with NASA AFRC
Juliet Page	Volpe	1. AFRC Pre-Test Detailed Test Plan Development

6.3.1 Experimental Review (NASA)

Communication between NASA and the WSPRRR team has been ongoing during development of the AFRC Pre-Test development, in the form of monthly Web-based oral progress reviews, supplemented with written documentation. This detailed test plan provides information about the test plan instrumentation and execution details. NASA program review of the AFRC Pre-Test will be held in the near future to review test plan details and solicit additional NASA input. An additional on-site coordination meeting will be held with NASA at AFRC prior to execution of the flight test.

6.3.2 Site Access

The WSPRRR will coordinate with NASA to obtain permissions to access sites at AFRC and EAFB for monitor setup as described in Section 4. The WSPRRR PI will also coordinate with the NASA Program Manager to ensure any security protocols and safety requirements (such as heat stress or desert tortoise training) are met for the on-site AFRC team prior to the text execution.

6.4 NASA - WSPRRR Team Communication

During the AFRC Pre-Test the communication structure and modes between NASA and the WSPRRR team members is itemized in Table 9. Cell phone carrier coverage with Verizon carrier service has been determined to be sufficient and is documented in Section 5.1.

Table 9 AFRC Pre-Test Communication Modes

- NASA Flight Control ←→F-18 Pilot
  - NASA Aircraft Instrumentation
- NASA Test Director ←→NASA Flight Control
  - Radio Comms (NASA provided equipment, Cell backup)
- NASA Flight Control ←→NASA PI, WSPRRR Co-PI
  - Radio Comms (NASA provided equipment, Cell backup) If necessary NASA PI and WSPRRR Co-PI can be co-located.
- NASA Test Director ←→NASA PI, WSPRRR PI & Co-PI
  - Radio Comms (NASA provided equipment, Cell backup)
- NASA PI, WSPRRR Co-PIs ←→Field Crew
  - Team Cell Phones / Text Messaging
- Field Crew ←→Field Crew
  - Team Cell Phones / Text Messaging

6.4.1 Communication Protocols

NASA will be responsible for communications with the flight test pilots. Communications from the NASA Flight Control Room is expected to be via NASA equipment and will be initiated by NASA. The NASA Test Director will issue key event communications via the PTT to the WSPRRR Co-PI including when aircraft have taken off, way points are reached / dive maneuvers are initiated. If workload permits (decision made during pre-test coordination) the NASA Test Director may also initiate group text messaging to the WSPRRR team when these key events have occurred. If necessary, the WSPRRR Co-PI will in turn relay such information to the WSPRRR test team via Cellular / Text Messaging. A group text message will be set up between the WSPRRR PI and the Field Crew prior to the WSPRRR Test.

The primary form of communication between NASA Flight Control / NASA Test Director with the NASA & WSPRRR Co-PIs shall be via NASA provided communication equipment (Verizon cell phones with push-to-talk (PTT) walkie-talkie features or comparable NASA provided equipment). Communications between the PIs and the instrumentation crew shall be via personal cell phones. It is not expected that NASA Flight Control or the Test director will need to communicate directly with the Field Crew, however NASA will be provided with a field crew cell phone list in advance of the Flight Test.

All field stations will be required to have a cell phone with adequate coverage and group text messaging capability. Field Crew shall provide the phone numbers to Volpe in advance of the WSPRRR experiment for distribution to all test members. Emergency contacts deemed important by NASA shall also be included on the communications list.

Prior to entering the field, a group text messaging chain will be established amongst the WSPRRR Co-PIs and the Field Crew.

6.4.2 Communication Equipment

We request that five NASA Provided Radios (PTT or equivalent) be issued to:

- NASA Flight Control
- NASA Test Director
- NASA PI
- WSPRRR Co-PI
- WSPRRR Co-PI

Cellular Phones with group text messaging feature will be self-provided by:

- WSPRRR PI
- WSPRRR Co-PI
- Each Field Crew Member

Although it is not necessary, communications can be facilitated by the following having access to cellular phones with group text messaging:

- NASA Test Director
- NASA PI

6.4.3 Radio Frequency Authorization

NASA will be responsible for obtaining any necessary RFA for the NASA provided PTT or comparable radios. Special authorization is not anticipated to be needed for use of Verizon cell phones with group chat capability.

6.5 Objective Instrumentation

The Objective instrumentation consists of acoustic monitoring equipment (described in Section 6.5.1) and meteorological instrumentation (described in Section 6.5.2).

6.5.1 Acoustic Instrumentation

The SBUDAS base station computer will be the point of control for all noise monitors. It is recommended that this computer along with its WR-21 Transport Cellular modem be located in the AFRC Pre-Test command center. At this location it will improve the reliability of communications with NASA Flight Control for SBUDAS noise monitor activation, status and recording.

Six SBUDAS noise monitors will be deployed as described in Section 4.2. Those monitors deployed on the AFRC site will remain deployed for the duration of the AFRC Pre-Test. Those monitors deployed on EAFB property, remote to AFRC, will be deployed on a daily basis and be accompanied by a WSPRRR engineer.

The voltage level on each SBUDAS Noise Monitor will be checked daily by a WSPRRR engineer prior to the commencement of and after the completion of each day's activities (pre-test and post-test each day).

Each SBUDAS noise monitor will be calibrated prior to the commencement of activities each morning and following the last flight in the afternoon. Calibration will require field crew to field crew communications between a WSPRRR Engineer at the SBUDAS base station computer and another WSPRRR Engineer at the SBUDAS noise monitor location. The calibration steps include:

1. The base station operator will then place the SBUDAS monitor in continuous record mode for 30 seconds.
2. When the recording is complete the base station operator will note the presence of the recorded file on the SBUDAS noise monitor.
3. The base station operator will retrieve the noise file and review it on the base station for accuracy.
4. The base station operator will then inform the WSPRRR engineer at the noise monitor location.
5. The WSPRRR engineer at the noise monitor location will then move on to the next noise monitor to repeat this process.

The three noise monitors remote to AFRC will be calibrated first, prior to their transport to their remote positions and again upon their collection upon conclusion of testing for each day.

Noise recordings during the AFRC Pre-Test will be executed as follows:

1. Prior to each flight all SBUDAS monitors will be activated by the base station operator.
2. One minute prior to the commencement of the low boom all SBUDAS monitors will be placed in record mode.
3. All recordings will be completed within one minute of the conclusion of the low boom delivery.
4. Upon completion of the noise recordings, maximum overpressure and loudness (PLdB) will be calculated by each noise monitor and automatically sent to the SBUDAS base station for review by the WSPRRR PI.
5. Between WSPRRR flights, each SBUDAS Monitor will be placed in Auto Mode for the retrieval of non-WSPRRR booms which may occur during the course of the test event

Upon the completion of all flights for each day the flash drives from each noise monitor will be retrieved for archival purposes.

6.5.2 Meteorological Instrumentation

NASA has indicated that they will make available two weather towers that stand about 10 feet tall. These sensors monitor wind speed/direction, temperature, relative humidity and pressure (2Hz sampling rate). It is recommended that one of the weather towers be deployed at AFRC in the vicinity of the SBUDAS noise monitor Foxtrot as shown in Figure 11. The second tower will be deployed with SBUDAS noise monitor Bravo on Yeager Boulevard near its intersection with Forbes Avenue and Mojave Boulevard. NASA will also provide access to a Weatherbug weather station installed at EAFB North Auxiliary Base from which surface weather observations will be archived on a continual basis to support post-test analysis.

In addition to these resources, hourly atmospheric surface measurements will be obtained and archived by the WSPRRR team via RSS datafeed from online National Weather Service resources (http://w1.weather.gov/xml/current_obs/) for Edwards AFB and the Auxiliary North Field Edwards AFB.

Upper Air Soundings (Radiosondes) will be collected by NASA as required for F-18 Low Boom Dive maneuver waypoint calculations. NASA will provide upper air meteorological data to the WSPRRR team for use in post-test analysis using PCBoom.

6.5.3 Flight Instrumentation

In order to facilitate PCBoom computation of sonic boom metrics and the participant daily dose, the WSPRRR team needs as-flown (processed/calibrated) F-18 trajectory data for each low boom dive maneuver executed during the WSPRRR program. The F-18s should be outfit with the necessary flight instrumentation for obtaining PCBoom trajectory data. NASA should provide this data to the WSPRRR team as soon as feasible after the flight test to facilitate post-test analysis.

6.6 Day of Flight

6.6.1 Go / No-Go Conditions

A Go / No-Go decision will be made by the NASA AFRC coordinator prior to each day's testing, and prior to each flight. The criteria implemented in WSPR will be utilized for Go / No-Go decisions.

Flights will not occur in the event of the following:

- Aircraft readiness or safety issues are not met, as determined by NASA
- Weather
  - Precipitation
  - Lightning. NASA's rules regarding lightning safety will be followed.
  - Meteorological Front within or passing through the airspace

- Communication system failure
- Instrumentation failure
    - Failure of flight instrumentation such that position and orientation information cannot be obtained or the aircraft cannot reliably perform the low-boom dive maneuver
    - Fewer than three SBUDAS Field Kit channels are operational
    - Failure to obtain initial (pre-flight) upper air data
    - Widespread internet or wireless outage in the EAFB area

6.6.2 Daily Flight Planning

Daily flight planning will be performed by NASA. This includes computation of the F-18 waypoints based on local GPSsonde upper air meteorological data. Daily flight planning also includes an assessment of the best flight cards to be flown depending on the atmospheric conditions. The experimental design includes some limited flexibility to allow for day of flight variations (see Section 2.2). With only 3 test days, it might not be possible to deliver the lowest booms (.13 psf), however this will not impact the potential to achieve all of the stated pre-test objectives.

6.7 Government Furnished Equipment and Services

The requested GFE and Services prior to the AFRC Pre-Test includes:

a. Site access and equipment installation permission coordination for AFRC/EAFB
b. Assistance with subject recruitment over a 3 week period prior to the Pre-Test

GFE during Pre-Test execution includes:

- F-18 low boom dive operations of up to 10 booms a day for 3 days over 1 week, including the services of NASA flight and ground crew personnel, F-18 aircraft and aircraft instrumentation.
- Day-of-flight F-18 waypoint calculation including acquisition of necessary meteorological data from NASA / EAFB radiosondes, weather towers and EAFB Aux North Weatherbug.
- Five radios (PTT or equivalent) for communications as described in Section 6.4
- NASA Public Affairs coordination as needed with the public and press.

Post-Test GFE includes:

- F-18 processed dive trajectory data for PCBoom footprint analysis
- NASA/EAFB Upper air meteorological data for PCBoom footprint analysis

6.8 Data Analysis Plans

Data analysis may be categorized into acoustic analysis, sonic boom analysis and dose-response analysis. Each WSPRRR sonic boom event will be numbered sequentially. If during the course of the test execution non-WSPRRR sonic booms are noticed they will be logged in the field notes.

6.8.1 Acoustic Analysis

In field acoustic analysis will include calculation of loudness metrics on as-recorded boom signatures for each sonic boom event. This data will be transmitted near-real time to the

SBUDAS base station for immediate assessment of boom delivery success. This will allow for adaptation of F-18 dive way points in order to meet the test design.

Final boom event numbers for WSPRRR and non-WSPRRR sonic booms will be assigned Post-Test. Post-test sonic boom analysis will include the calculation of noise metrics at each monitoring station based on the recorded pressure waveforms. This data will be cataloged into a spreadsheet and correlated with WSPRRR flight logs. Non-WSPRRR booms will be identified and cataloged with the sonic boom database. Additional information about the sonic booms, such as monitor location, arrival time, indication of possible turbulence, carpet and/or focus boom labeling, local meteorological conditions, WSPRRR/non-WSPRRR boom and relevant field notes. This data will be provided to the WSPRRR team for further analysis including determination of sonic boom metrics at participant locations and correlation with subjective responses.

6.8.2 Sonic Boom Analysis

Prior to execution of each F-18 flight, NASA will conduct a sonic boom analysis in order to determine the way points for low boom dive flights. Between individual dives from a given flight, the way points will be adjusted accordingly to achieve the desired boom design levels.

Post-test PCBoom analysis will be conducted for each WSPRRR F-18 dive maneuver based on NASA provided tracking data and best available upper air meteorological data. This analysis will be used to refine the participant metrics and boom/dose level calculations. The participant metric refinements will include 1) empirical 2-D linear interpolation based on position between noise monitors and 2) hybrid empirical-analytical interpolation using PCBoom predicted metric gradients based on as-flown F-18 trajectories and historical upper-air meteorological data. The footprints from the F-18 dive maneuver are considerably more complex than those anticipated for the future QueSST dose-response test sonic boom footprints so uncertainties are likely to be higher for the AFRC pre-test, however it will provide an opportunity to test and refine the hybrid empirical-analytical interpolation technique.

6.8.3 Dose Response Analysis

The PSU SRC will obtain participant survey responses for each day of flight testing.

Post-test the participant reported geo-location data will be determined for each participant and each sonic boom event and linked to WSPRRR and non-WSPRRR boom event number based on the survey response times and reported boom times. The participant locations for each boom will be provided to the WSPRRR team. This participants will be de-identified as described in Section 4.

When the acoustic data (closest-monitor, linear empirical interpolation and refined hybrid analytical/empirical boom/dose levels) are available, the survey responses will be correlated with each flight and a database prepared for potential statistical dose-response analysis. (Note: in depth dose-response statistical analysis will not be conducted on the ARFC pre-Test dataset).

6.9 Safety and Security

6.9.1 Flight Operations (NASA Responsibility)

Safety and security associated with the F-18 flight operations will be the responsibility of NASA.

6.9.2 Ground Personnel Safety

The WSPRRR team will be responsible for complying with all NASA AFRC and EAFB rules and regulations. Specific safety training is not anticipated. In-field safety will be facilitated by following all regulations and rules regarding site access, vehicle operations and equipment operation. Each member of the WSPRRR team will have a cell phone in the case of emergency. Additionally, a communications list which will include relevant emergency phone numbers as determined by NASA, will be distributed to all team members.

7 Post-Test Responsibilities

7.1 Instrumentation Test Sites

7.1.1 Acoustic Instrumentation Data

Acoustic data from each noise monitor will be stored locally on flash drives. At the end of each day of flight / acoustic measurements, the raw unprocessed high-fidelity acoustic (voltage) data will be backed up on separate media. Immediately following the test completion and prior to return shipment of the equipment, a backup of the raw measurement data will be provided to NASA. Shortly after the test, the data will be calibrated, files will be assembled into an acoustic data archive and correlated with the boom event numbers and field notes for delivery to the WSPRRR team to facilitate the calculation of sonic boom metrics.

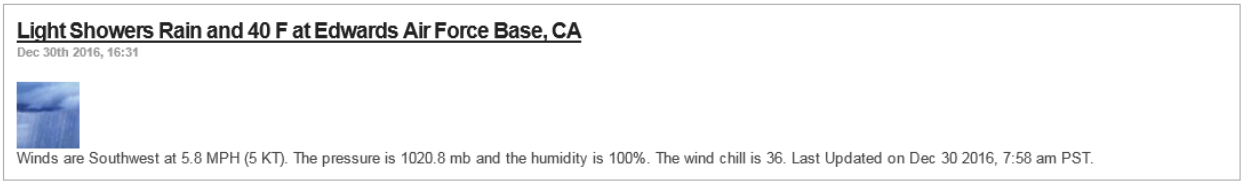
7.1.2 Meteorological Instrumentation Data

Surface weather observations will be collected through data feeds and NASA weather towers. Parameters to be archived are listed in Table 10. This data will be utilized to support acoustic data analysis following execution of the AFRC Pre-Test. It is anticipated that this surface weather data will assist in the assessment of turbulence and its impact on methods for determining noise dose at a participant's location.

Table 10 Surface Weather Instrumentation Data

Parameter	Units
Position	Latitude/Longitude
Time	DDMMYY hhmmss
Air Temperature	Degrees Fahrenheit
Atmospheric Pressure	Millibars
Wind Direction	Cardinal Compass Headings
Wind Speed	Knots
Relative Humidity	%

The weather towers collect weather data twice a second therefore we are assured that accurate data will be collected at these locations at the time that the low boom noise does is received. The National Weather Service RSS data feed will provide hourly observation data through emailed responses as shown in Figure 12.



Light Showers Rain and 40 F at Edwards Air Force Base, CA
Dec 30th 2016, 16:31

Winds are Southwest at 5.8 MPH (5 KT). The pressure is 1020.8 mb and the humidity is 100%. The wind chill is 36. Last Updated on Dec 30 2016, 7:58 am PST.

Figure 12 National Weather Service Hourly Observation email

Each morning for which flights are planned, and again prior to each subsequent flight, a rawinsonde observation will be collected by NASA. This rawinsonde may be launched by Air Force Weather personnel from the Rawinsonde Road on EAFB, approximately 1.66 miles from AFRC as shown in Figure 13.

Figure 13 Rawinsonde Launch Site

The rawinsonde data output is presented in Figure 14. This data will be utilized by NASA for the calculation of Low Boom Dive Maneuver waypoints and pre-flight PCBoom forecasts of the Low Boom footprint. The same meteorological data will be used post-test to facilitate computation of refined boom/dose levels for participants at their reported geo-locations at the time of each sonic boom.

KEDW (723810) 13-DEC-2016 00Z NAMNEST 00HR FORECAST SOUNDING VALID 13-DEC-2016 00Z													
ALT	DIR	SPD	SHR	TEMP	DPT	PRESS	RH	ABHUM	DENSITY	I/R	V/S	VPS	PW
MSL FT	DEG	KTS	/SEC	DEG C	DEG C	MBS	PCT	G/M3	G/M3	N	KTS	MBS	MM
2339	0	0	0	-5.5	-53.4	933.7	1	0.03	1215.31	271	638	0.04	0
3000	271	10.6	0.027	16	-1.6	911.86	30	4.08	1096.35	269	664	5.44	0
4000	278	13	0.005	13.5	-3	879.59	31	3.66	1066.76	260	661	4.84	2
5000	291	14.1	0.006	11.1	-4	848.23	34	3.45	1037.32	252	658	4.52	3
6000	290	15.1	0.002	9.7	-3.9	817.8	38	3.52	1005.28	246	656	4.59	4
7000	284	18.5	0.007	8.4	-2.3	788.34	47	3.98	973.14	242	655	5.17	5
8000	286	22.5	0.007	6.9	-1	759.81	57	4.35	942.7	237	653	5.62	6
9000	287	27.6	0.009	5	-1	732.16	65	4.43	914.46	232	651	5.68	7
10000	288	33.1	0.009	3.6	-1.7	705.35	68	4.2	885.49	224	649	5.36	9
11000	286	37.2	0.007	2.4	-2.9	679.44	68	3.86	856.73	215	648	4.91	10
12000	285	41	0.007	0.6	-5	654.33	65	3.3	830.63	206	646	4.17	11
13000	283	44.6	0.006	-1.4	-8.5	630.01	58	2.54	806.02	196	643	3.19	12
14000	281	48	0.007	-3.3	-13.5	606.43	45	1.72	781.94	185	641	2.14	13
15000	278	51.3	0.007	-5.1	-21.5	583.51	27	0.91	757.83	175	638	1.13	13
16000	275	52.6	0.005	-6.7	-28	561.35	17	0.51	733.6	167	636	0.63	13
17000	273	54.7	0.004	-8.5	-30	539.91	16	0.43	710.39	161	634	0.53	13
18000	273	58.2	0.006	-10.6	-27.6	519.17	23	0.53	688.47	157	632	0.64	14
19000	272	61	0.005	-12.5	-27.1	499.03	28	0.55	666.61	152	629	0.66	14
20000	272	63.2	0.004	-14.3	-27	479.56	33	0.56	645.18	148	627	0.67	14
21000	272	65.1	0.003	-16.2	-27.1	460.76	38	0.56	624.29	143	625	0.66	14
22000	272	66.3	0.002	-18.1	-27.6	442.52	43	0.54	604.09	138	623	0.64	14
23000	273	67.3	0.002	-20.2	-27.5	424.89	53	0.56	584.76	134	620	0.65	14
24000	274	67.9	0.003	-22.4	-26.8	407.86	68	0.59	566.28	130	617	0.68	15
25000	274	68.4	0.002	-24.4	-27.8	391.32	74	0.54	547.75	126	615	0.62	15
26000	275	69	0.001	-26.4	-29.2	375.41	77	0.48	529.66	121	613	0.54	15
27000	273	68.5	0.003	-28.6	-31.6	359.92	75	0.38	512.5	117	610	0.43	15
28000	272	68.2	0.003	-30.8	-34	345.05	73	0.3	495.91	113	607	0.34	15
29000	271	71.1	0.005	-33	-36.2	330.57	72	0.25	479.42	109	604	0.27	15
30000	270	74.1	0.005	-35.2	-38.4	316.69	72	0.2	463.49	105	601	0.22	15
31000	271	77.4	0.006	-37.3	-40.7	303.15	70	0.16	447.63	101	599	0.17	15
32000	271	80.8	0.006	-39.4	-43	290.2	67	0.12	432.35	97	596	0.13	15
33000	271	84	0.006	-41.8	-45.5	277.57	67	0.1	417.87	94	593	0.1	15
34000	272	87.3	0.006	-44.2	-47.9	265.48	66	0.07	403.93	91	590	0.08	15
35000	272	90.3	0.005	-46.8	-50.6	253.71	64	0.05	390.42	87	587	0.06	15
36000	272	93.2	0.005	-49.4	-53.4	242.41	62	0.04	377.38	84	583	0.04	15
37000	273	96.9	0.007	-51.9	-56	231.44	60	0.03	364.36	81	580	0.03	15
38000	275	100.9	0.008	-54.3	-58.4	220.9	59	0.02	351.65	78	577	0.02	15
39000	276	105.3	0.009	-56.6	-60.5	210.7	60	0.02	338.98	76	574	0.02	15
40000	278	109.9	0.009	-58.9	-62.5	200.91	62	0.01	326.64	73	571	0.01	15
41000	280	112.6	0.008	-61.3	-64.1	191.43	69	0.01	314.81	70	567	0.01	15
42000	282	114.7	0.008	-63.8	-65.6	182.35	77	0.01	303.45	68	564	0.01	16
43000	282	112.6	0.004	-65.9	-67.5	173.56	78	0.01	291.72	65	561	0.01	16
44000	283	109.7	0.005	-67.9	-69.6	165.17	78	0	280.31	62	558	0	16
45000	282	103.6	0.011	-69.4	-72.5	157.07	64	0	268.51	60	556	0	16
46000	281	98.1	0.01	-70.5	-74.8	149.36	52	0	256.74	57	555	0	16
47000	279	94.4	0.008	-70.4	-75.1	142	49	0	243.95	54	555	0	16
48000	278	90.8	0.007	-70.2	-75.4	135	46	0	231.72	52	555	0	16
49000	277	87.4	0.006	-69.8	-75.7	128.37	41	0	219.96	49	556	0	16
50000	276	84.7	0.005	-69.6	-76	122.06	38	0	208.96	47	556	0	16
51000	275	83.8	0.002	-69.8	-76.3	116.07	37	0	198.84	44	556	0	16
52000	275	82.9	0.002	-69.9	-76.7	110.37	36	0	189.22	42	556	0	16
53000	275	82	0.002	-70.1	-77	104.95	35	0	180.11	40	555	0	16
54000	276	81.2	0.002	-70.4	-77.3	99.79	34	0	171.44	38	555	0	16
55000	277	77.8	0.006	-70.4	-77.7	94.88	33	0	163.06	36	555	0	16
56000	279	73.9	0.007	-70.5	-78	90.22	31	0	155.07	35	555	0	16
57000	280	69.7	0.008	-70.5	-78.3	85.78	30	0	147.46	33	555	0	16
58000	282	64.8	0.009	-70.5	-78.6	81.57	28	0	140.19	31	555	0	16
59000	284	60	0.009	-70.4	-78.9	77.56	27	0	133.28	30	555	0	16
60000	286	55.6	0.008	-70.3	-79.2	73.75	25	0	126.65	28	555	0	16
61000	285	51.7	0.007	-69.9	-79.5	70.14	23	0	120.25	27	556	0	16
62000	285	47.7	0.007	-69.6	-79.8	66.71	21	0	114.18	25	556	0	16
63000	284	43.9	0.007	-69.3	-80.1	63.44	19	0	108.42	24	557	0	16
64000	283	41.3	0.005	-69	-80.4	60.36	17	0	102.98	23	557	0	16
65000	282	38.7	0.005	-68.6	-80.7	57.43	16	0	97.81	22	557	0	16
66000	280	36.2	0.005	-68.3	-81	54.63	14	0	92.91	21	558	0	16
67000	279	33.9	0.004	-67.9	-81.2	51.98	13	0	88.23	20	558	0	16
68000	281	33.3	0.002	-67	-81.5	49.49	11	0	83.64	19	560	0	16
69000	283	32.6	0.002	-66.1	-81.8	47.12	10	0	79.29	18	561	0	16
70000	284	32	0.002	-65.2	-82.1	44.87	9	0	75.17	17	562	0	16

Figure 14 Rawinsonde Data output

A Appendix: Low Boom AFRC Recruitment Letter

Spring 2017

This May NASA plans to conduct several days of sonic boom flight tests over Edwards AFB. NASA has developed a method for generating sonic boom noise similar to that anticipated for quiet supersonic flight. A team of researchers sponsored by NASA is conducting research on people's attitudes about aircraft noise. We are seeking volunteers from the NASA Armstrong Flight Research Center to give feedback that provides insights into how individuals experience this noise in their homes and workplace.

The study will take place in May 2017 at Edwards Air Force Base. Participants will be asked to complete a brief set of questions each time they hear a sonic boom over a few days. To be eligible, participants must

- work at NASA Armstrong Flight Research Center
- be 18 years of age or older
- be on EAFB at least part of the day during weekday, daytime hours
- be willing to use your own smartphone with location services on to complete surveys

NASA is working with the Penn State Survey Research Center to help conduct the study. If you would like to join our study and help with this important research please contact Penn State Survey Research Center at 1-800-648-3617 or email Brian Sonak at bcs5@psu.edu. Self-registration is available at < www.src.survey.psu.edu/nasa >.

Participation is voluntary and survey responses will be confidential. The information provided will be used for research purposes and will not reveal individual identification. If you have any questions about this study, you can contact Kathleen Hodgdon of Penn State University at kkh2@psu.edu or at (814) 865-2447.

We appreciate your help and support!

Respectfully,

Alexandra Loubeau NASA LaRC
Larry Cliatt NASA AFRC
Kathleen Hodgdon Team Co-Prinicipal Investigator and Robert Hunte Team Lead

Please contact us at
www.src.survey.psu.edu/nasa
1-800-648-3617
Brian Sonak at bcs5@psu.edu

Answers to Frequently Asked Questions

Who is conducting this study?
NASA is sponsoring this research. Penn State Survey Research Center is recruiting volunteers from the NASA Armstrong Flight Research Center to give feedback that provides insights into how individuals experience noise in their workplace and homes.

Why is this study being done?
A multi-disciplinary research team is investigating low boom community noise impact and analyzing survey responses about noise perception. The research team is sponsored by NASA, led by Applied Physical Sciences, with co-principal investigators from both Applied Physical Sciences and Penn State. In addition to researchers at Applied Physical Sciences and Penn State, the team includes research members from Eagle Aeronautics, Gaugler Consulting, Gulfstream Aerospace, Volpe National Transportation Systems Center, and Wyle Laboratories. Data from this research study will help NASA understand the impact of sonic booms on people.

When will the study be done?
The study will be conducted in May 2017 over the course of several days.

What will participants be asked to do?
In a brief background survey, we will ask questions about demographic characteristics and attitudes so that we can accurately describe the group of participants. Participants will be asked to answer a few questions each time they hear a sonic boom over approximately a three-day period. They will also complete a brief summary questionnaire at the end of each day.

Will I receive anything for participating?
Yes. Participants will receive a certificate of appreciation from NASA.

Whom do I contact for more information about this research?
For information about registration or technical issues with completing the survey please call 814-863-6201 or email Brian Sonak at bcs5@psu.edu.

If you have questions about the research study, please contact Kathleen Hodgdon of Penn State University at kkh2@psu.edu or at (814) 865-2447.

For information about the research program and how the study results will be used, please contact Larry J. Cliatt, NASA Armstrong Flight Research Center at (661) 276-7617 or larry.j.cliatt@nasa.gov

You may also contact Kevin Rohrer Chief, Strategic Communications, NASA Armstrong Public Affairs Office at 661-276-3595 or at kevin.j.rohrer@nasa.gov

B Appendix: Low Boom Recruitment Flyer

Volunteers Needed

A team of researchers sponsored by NASA is conducting a study on people's attitudes about sonic boom noise. We are seeking volunteers from the NASA Armstrong Flight Research Center to participate in a survey.

The study will take place in May 2017. Participants will be asked to complete survey questions each time they hear a sonic boom over a few days. To be eligible, participants must

- work at NASA Armstrong Flight Research Center
- be 18 years of age or older
- be on EAFB at least part of the day during weekday, daytime hours
- be willing to use your own smartphone with location services on to complete surveys

NASA is working with the Penn State Survey Research Center to help conduct the study. Self-registration is available at

< **www.src.survey.psu.edu/nasa** >

Participation is voluntary and survey responses will be confidential.

Please contact us at
www.src.survey.psu.edu/nasa
1-800-648-3617
or email Brian Sonak at bcs5@psu.edu

C Appendix: Low Boom AFRC Test Recruitment and Self Registration

Low Boom Response AFRC Test
Recruitment Screening and Self Registration
www.src.survey.psu.edu/nasa
[PSU sponsored web survey for NASA AFRC employees who want to participate]

Thank you for your interest in participating in a NASA sponsored study that will take place in May 2017 at Edwards Air Force Base. Participants will be asked to complete a brief set of questions each time they hear a sonic boom over a few days. To be eligible, participants must

- work at NASA Armstrong Flight Research Center
- be 18 years of age or older
- be on EAFB at least part of the day during weekday, daytime hours
- be willing to use your own smartphone with location services on to complete surveys

NASA is working with the Penn State Survey Research Center to help conduct the study. If you would like to join our study and help with this research please answer the following questions and complete your registration below.

Your participation is voluntary. If we ask a question you do not want to answer, just go to the next question. The information you provide will be used for research purposes and will not reveal individual identification. If you have any questions about this study, you can contact Kathleen Hodgdon of Penn State University at (814) 865-2447. The following questions will help us identify whether you are eligible to participate.

Q1 Do you currently work at NASA Armstrong Flight Research Center?
1 Yes
2 No See comment below.
If your answer to Q1 is 2 (No) then you are not eligible to participate. Thank you for your interest. Only employees of AFRC can participate.

Q2 The next questions ask about the time you are at EAFB. We need to know if participants will be able to tell us about noise in their area during different times of the day. Think about the weekdays Monday through Friday between 8 o'clock in the morning and 5 o'clock in the evening. On how many week days are you usually on EAFB at least part of the day during these hours?

______ number of days (enter number between 0 and 5)
If your answer to Q2 is 0 (No week days on EAFB) then you are not eligible to participate. Thank you for your interest.

Q3 On a weekday when you are working, how many hours are you usually on EAFB in the **morning** that is between 8 o'clock in the morning and noon?

______ number of hours (enter number between 1 and 4)
0 Less than 1 full hour

9 Not usually on EAFB during this time

Q4 On a weekday when you are working, how many hours are you usually on EAFB in the **afternoon** that is between noon and 5 o'clock in the evening?

______ number of hours (enter number between 1 and 5)
0 Less than 1 full hour
9 Not usually on EAFB during this time

Q5 Do you move around AFRC and between buildings during an average work day?
1 Yes
2 No

Q6 To the best of your knowledge is your hearing normal?

1 Yes [skip to Q8]
2 No

Q7 Do you use a hearing aid?

1 Yes
2 No

Participants will be asked to complete the short questionnaire using their own Smartphone, mobile device or computer each time they hear a sonic boom.

Q8 We will provide a web based survey application so you can post your responses. Would you be willing to use your own SmartPhone, mobile device or computer as part of this study? This would be at your own expense.

1 Yes
2 No

If your answer to Q8 is 2 (No) then you are not eligible to participate. Thank you for your interest.

Q9 We require that your mobile device has Global Positioning System (GPS) enabled on the Location Services in your device setting. The GPS will be used to determine your location, so that we can associate your response with the noise monitor that is closest to that location. Would you be willing to answer survey questions with a SmartPhone with the GPS location services enabled?

1 Yes
2 No

Q10 Thank you. To make sure that we can reach you, would you please provide the following information?
Name:
Address:
Telephone number:
Mobile telephone number:

Email address:

D Appendix: Low Boom AFRC Background Survey and Implied Informed Consent

Low Boom Response AFRC Background Survey
[smart phone/web based implementation]

Thank you for volunteering to participate in this research study about noise from sonic booms at Edwards Air Force Base. This study is being conducted for research purposes, to gather responses about the perception of low-level sonic booms. The research team is sponsored by NASA, led by Applied Physical Sciences, with co-principal investigators from both Applied Physical Sciences and Penn State. In addition to researchers at Applied Physical Sciences and Penn State, the team includes research members from Eagle Aeronautics, Gaugler Consulting, Gulfstream Aerospace, Volpe National Transportation Systems Center, and Wyle Laboratories.

(Implied Consent) We appreciate your participation, which is voluntary and confidential. There is no compensation for participation. If there is a question you do not want to answer, you may skip that question and move on to the next question. Your responses will be associated with your participant number and summarized so that the answers you provide cannot be associated with you or your household. You must be 18 years of age or older to consent to participate in this research. ***Responding to the survey questions implies your consent to participate in this background survey, and in the 3 day field study being conducted at Armstrong Flight Research Center at Edwards Air Force Base.*** During the 3 day test period you will go about your normal activities. You will be asked to complete a short survey each time that you hear a boom during the day. Please provide your responses as soon as possible after hearing each boom. You will also be asked to complete a short daily survey at the end of each day, providing a rating of your perception of the noise over that particular day.

Participants will use their own smart phones to respond using Qualtrics, a phone based survey application, or their own tablets, computers or devices if they choose to complete the surveys on the web. We require you to have location services activated on the device you use to complete the survey. Your location is required to associate the location where you are when you hear the boom with the noise measured at the location of the nearest noise monitor.

Your confidentiality will be kept to the degree permitted by the technology used. No guarantees can be made regarding the interception of data sent via the Internet by any third parties. However, no personal identifiers (name, address) are included on any survey forms, only anonymous Respondent IDs or numbers.

Since your participation is voluntary, you may stop at any time. Please notify the researchers if you decide to withdraw from the study. If you have any questions about this study, you can contact Penn State principal investigator Kathleen Hodgdon at kkh2@psu.edu. If you have technical difficulties with the survey applications please contact Penn State project manager

Brian Sonak at bcs5@psu.edu, or call the Penn State Survey Research Center at 1-800-648-3617. If you have questions regarding your rights as a research subject or concerns regarding your privacy, you may contact the Penn State Office for Research Protections at 814-865-1775.

A1 Please provide the street address and or building where you are during most of the work day at Edwards Air Force Base.

A2 Do you live on Edwards Air Force Base?

1 Yes
2 No

A3 Please provide your current home address (required for noise responses provided from your home location rather that your work location)

A4 Please provide your email address.

Social and Demographic Characteristics

B1 What is your gender?
Male
Female

B2 In what year were you born? [Enter 4-digit year]

B3 Including yourself, how many people live in your household?

_____ Number

B4 [IF B3 > 1] Do any children under age 6 live in your household?

1 Yes
2 No

B5 [IF B3 > 1] Including yourself, how many adults age 18 or older live in your household?

_____ Number

B6 What is the highest grade or year of schooling that you completed? (Select one)

1 Grades 1 to 11
2 12th Grade No Diploma
3 High School Graduate or Equivalent (GED)

4 Some college, technical school, or 2-year degree
5 Bachelor's Degree (BA, AB, BS)
6 Some graduate work (no degree)
7 Masters, Doctoral, or Professional degree

B7 Do you believe that your hearing is normal? How would you characterize your hearing ability?

1 Normal (Go to C1)
2 Somewhat diminished (Go to B8)
3 Severely diminished (Go to B8)

B8 [If B7>1] Do you own and wear a hearing aid, or hearing aids?

1. Wear a single hearing aid
2. Wear two hearing aids
3. Have hearing aids that I don't wear

B9 Which of the following best describes the type of home in which you live?

1 Single-family detached (no common walls)
2 Duplex or single-family attached (at least one common wall)
3 Apartment building or dormitory
4 Other [SPECIFY] [text box]

B10 The research team may need to put noise monitoring equipment in residents' yards for the duration of the test. Would you be willing to have noise monitoring equipment located outdoors on your property?
[SELECT ONE]

1 Yes
2 No
3 Depends

Attitudes and Experience with Neighborhood Noises

C1 We're interested in the noises that people hear in their neighborhood. Do you think your neighborhood is quiet or noisy or about average? Please select one.

1 Quiet
2 Noisy
3 Average

C2 For each statement, please indicate if you strongly disagree, moderately disagree, neither agree nor disagree, moderately agree or strongly agree.

a. I believe that people have a hard time getting used to noise.
   1 Strongly disagree
   2 Moderately disagree
   3 Neither agree nor disagree
   4 Moderately agree
   5 Strongly agree

b. I believe that with time most people adapt to noise.
   1 Strongly disagree
   2 Moderately disagree
   3 Neither agree nor disagree
   4 Moderately agree
   5 Strongly agree

c. I believe that with time I can adapt to noise.
   1 Strongly disagree
   2 Moderately disagree
   3 Neither agree nor disagree
   4 Moderately agree
   5 Strongly agree

d. I believe that with time I can get used to even the loudest noise.
   1 Strongly disagree
   2 Moderately disagree
   3 Neither agree nor disagree
   4 Moderately agree
   5 Strongly agree

C3. Next is a list of noises that might occur in your neighborhood. Please indicate how much each noise bothers, disturbs or annoys you. Use a scale from 0 to 5 where 0 means “not at all bothered or annoyed” and 5 means “extremely bothered or annoyed.”

When you are at home, how much does noise from < noise source > bother, disturb, or annoy you?

- Barking Dogs
  0 – 5 Select a rating from 0 (not annoyed) to 5 (extremely annoyed)
- Thunder
  0 – 5 Select a rating from 0 (not annoyed) to 5 (extremely annoyed)
- Street traffic such as cars, trucks or motorcycles
  0 – 5 Select a rating from 0 (not annoyed) to 5 (extremely annoyed)
- Commercial Aircraft noise
  0 – 5 Select a rating from 0 (not annoyed) to 5 (extremely annoyed)
- Military aircraft noise, not including sonic boom noise
  0 – 5 Select a rating from 0 (not annoyed) to 5 (extremely annoyed)
- Sonic booms

0 – 5   Select a rating from 0 (not annoyed) to 5 (extremely annoyed)

C4 How long have you lived near Edwards Air Force Base?

_____ [enter number of years]
0   Less than 1 full year

C5 Have you heard sonic booms before you came to EAFB?
1   Yes
2   No

C6 Compared to the neighborhood where you lived before you moved to Edwards Air Force Base, would you say the noise at Edwards Air Force Base is much less annoying, somewhat less annoying, about the same, somewhat more annoying, or much more annoying?

- Much less annoying
- Somewhat less annoying
- About the same
- Somewhat more annoying
- Much more annoying

Experience with Sonic Booms (for AFRC participants only)

D1 The next questions ask about your experience with sonic booms when you are at home.

How **loud** is noise from sonic booms when you are in or near your home? Please use a scale from 0 to 5 where 0 means “not at all loud” and 5 means “extremely loud.”

0 – 5   [Enter a number between 0 and 5]

D2 How much does noise from sonic booms **interfere** with your ability to talk with others or hear conversations **inside** your home?

[REPEAT AS NECESSARY: Please use a scale from 0 to 5 where 0 means “not at all” and 5 means “extremely.”]

0 – 5   [Enter a number between 0 and 5]

D3 How much does noise from sonic booms **interfere** with your ability to talk with others or hear conversations **outside** your home?

0 – 5   [Enter a number between 0 and 5]

D4 How much does noise from sonic booms **startle you or make you jump**?

0 – 5 [Enter a number between 0 and 5]

D5 Vibration is a motion. The motion may be seen or felt. Using a scale from 0 to 5 where 0 means “none” and 5 means “a great deal,” how much **vibration** from sonic booms do you see or feel in your home?

0 – 5 [Enter a number between 0 and 5]

D6 Rattle is a type of noise that can occur when objects move due to a vibration. Using a scale from 0 to 5 where 0 means “none” and 5 means “a great deal,” how much **rattle** from sonic booms do you experience in your home?

0 – 5 [Enter a number between 0 and 5]

Thank you! As part of the research study, you will be asked to complete a short questionnaire each time you hear a sonic boom over a 3-day period. Please answer these questions as soon after hearing the boom as possible. The questions will ask things like what time you heard the sonic boom, your location when you heard the boom, whether you were inside or outside, and how you reacted to the noise. We will also ask you to complete a short survey at the end of each day, telling us about the sonic booms you heard.

E Appendix: Single Event Response Form

Low Boom Community AFRC Test
Subjective Response to Flight Test Booms

Single Event Response Form
Formatted for administration by web and SmartPhone

[Self-administered questionnaire completed after each single sonic boom event]

Single Boom Event Time and Location

E1 Date of the sonic boom: [MM/DD/YY]

E2 Time of the sonic boom:

E3 Did your location show correctly on the survey geo-location application?
1 Yes
2 No

E4 Where were you when the sonic boom occurred?

At home and inside	[go to E8]
Near home and outside	[go to E5]
At work and inside	[go to E8]
Near work and outside	[go to E6]
Not near home or work	[go to E7]

E5 Were you within 3-4 blocks of your home? [go to E8]
1 Yes
2 No

E6 Were you within 3-4 blocks of work? [go to E8]
1 Yes
2 No

E7 Please provide the nearest street address to where you heard this boom
[Text box for open ended address response] [go to E8]

Single Boom Event Response Ratings

E8 How much did the sonic boom **bother, disturb**, or **annoy** you? (Use a scale from 0 to 5 where 0 means “not at all” and 5 means “extremely.”)

E9 How **loud** was the sonic boom? (Use a scale from 0 to 5 where 0 means “not at all loud” and 5 means “extremely loud.”)

E10 How much did the sonic boom **interfere** with your activity? (Use a scale from 0 to 5 where 0 means “not at all” and 5 means “extremely.”)

E11 Some routine activities can create background noise. Thinking about what you were doing when the sonic boom occurred, please rate how **loud** the noise of **that activity** was. Use a scale from 0 to 5 where 0 means “not at all loud” and 5 means “extremely loud.”

E12 Briefly describe the noise environment when you heard the sonic boom
Working or relaxing in a quiet environment
Working or relaxing near a busy road
Working or relaxing with the air conditioner or a ceiling fan running
Working or relaxing with a device or appliance running (TV, music)
Mowing the lawn or operating other power tools or equipment
Other (specify)
None of the above

E13 Vibration is a motion. The motion may be seen, felt or heard. How much **vibration** from the sonic boom did you see or feel? (Use a scale from 0 to 5 where 0 means “none” and 5 means “a great deal.”)

E14 Rattle is a type of noise that can occur when objects move due to a vibration. How much **rattle** from the sonic boom did you experience? (Use a scale from 0 to 5 where 0 means “none” and 5 means “a great deal.”)

E15 Please enter any additional comments. [text box]

F Appendix: Daily Summary Response Form

Low Boom Response AFRC Test
Daily Response to Flight Test Booms

Daily Summary Response Form
[To be formatted for administration by web and SmartPhone]

[Self-administered questionnaire completed at the end of each day]

A1 Date: MM/DD/YY

A2 How many hours were you **at or near home** today between 8:00AM and 7:00PM?

Zero	None	[go to A10]
1 – 11	Enter number 1 to 11	

A3 During the time you were **near home** today, how many sonic booms did you hear?

Zero	None	[go to A10]
1 – 20	Enter number 1 to 20	

For the next few questions, please think about the sonic booms you heard while you were **near home** today *whether you were inside or outside* when they occurred.

A4 How much did the sonic booms **bother, disturb**, or **annoy** you? Use a scale from 0 to 5 where 0 means “not at all” and 5 means “extremely.”

A5 How **loud** were the sonic booms? (Use a scale from 0 to 5 where 0 means “not at all loud” and 5 means “extremely loud.”)

A6 How much did the sonic booms **interfere** with your activities? (Use a scale from 0 to 5 where 0 means “not at all” and 5 means “extremely.”)

A7 Vibration is a motion. The motion may be seen, felt or heard. How much **vibration** from the sonic booms did you see or feel in your home today? (Use a scale from 0 to 5 where 0 means “none” and 5 means “a great deal.”)

A8 Rattle is a type of noise that can occur when objects move due to a vibration. How much **rattle** from the sonic booms did you experience in your home today? (Use a scale from 0 to 5 where 0 means “none” and 5 means “a great deal.”)

A9 During the time you were **near home** today, were your windows closed most of the time or were they open most of the time?

1 Open most of the time
2 Closed most of the time

A10 How many hours were you **at or near work** today between 8:00AM and 7:00PM?

Zero	None
1 – 11	Enter number 1 to 11

A11 During the time you were **near work** today, how many sonic booms did you hear?

Zero	None
1 – 20	Enter number 1 to 20

For the next questions, please think about the sonic booms you heard while you were **near work** today whether you were inside or outside when they occurred.

A12 How much did the sonic booms **bother, disturb,** or **annoy** you? Use a scale from 0 to 5 where 0 means “not at all” and 5 means “extremely.”

A13 How **loud** were the sonic booms? (Use a scale from 0 to 5 where 0 means “not at all loud” and 5 means “extremely loud.”)

A14 How much did the sonic booms **interfere** with your activities? (Use a scale from 0 to 5 where 0 means “not at all” and 5 means “extremely.”)

A15 Vibration is a motion. The motion may be seen, felt or heard. How much **vibration** from the sonic booms did you see or feel in your home today? (Use a scale from 0 to 5 where 0 means “none” and 5 means “a great deal.”)

A16 Rattle is a type of noise that can occur when objects move due to a vibration. How much **rattle** from the sonic booms did you experience in your home today? (Use a scale from 0 to 5 where 0 means “none” and 5 means “a great deal.”)

A17 During the time you were **near work** today, were your windows closed most of the time or were they open most of the time?

1. Open most of the time
2. Closed most of the time

A18 Did you hear any noises today that might have been sonic booms but you are not sure?

1. Yes
2. No [go to A20]

A19 Please describe what that noise sounded like. [text box]

A20 Please enter any additional comments. [text box]

G Appendix: Post Test Feedback Form

Low Boom Response AFRC
Post Test Feedback Survey

Thank you for your recent participation in the research study about noise from sonic booms at Armstrong Flight Research Center.

A1 We're interested in how easy it was to use the geo-location and survey response instruments.

1. Not at all easy
2. Slightly easy
3. Moderately easy
4. Very easy
5. Extremely easy

A2 Were the text notifications helpful?

1 Yes
2 No

A3 Can you provide additional feedback or comments so that we can improve our survey methods?

Thank you. We appreciate your help with this research study.

H Appendix: News Release (if needed)

This research investigates elements related to the potential approval of supersonic flight over land for low boom aircraft. NASA has developed an F-18 flight technique for generating sonic boom noise similar to that anticipated for quiet supersonic flight. The planning and execution of human response studies will gather data to correlate human annoyance response with low level sonic boom noise. The efforts include assessment of community noise impact and methods to assess public acceptability of low boom signatures.

Flight tests are being conducted at NASA Armstrong Flight Research Center for three days over a one week period in May. A multi-disciplinary research team is investigating low boom community noise impact and analyzing survey responses about noise perception. The research team is sponsored by NASA, led by Applied Physical Sciences, with co-principal investigators from both Applied Physical Sciences and Penn State. In addition to researchers at Applied Physical Sciences and Penn State, the team includes research members from Eagle Aeronautics, Gaugler Consulting, Gulfstream Aerospace, Volpe National Transportation Systems Center, and Wyle Laboratories. Data from this research study will help NASA understand the impact of sonic booms on people.

I Appendix: References

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G. NASA Low Boom Flight Demonstrator Community Response Pre-Test Armstrong Flight Research Center May 8-12, 2017

The following pages provide Appendix G. This appendix file is provided separately from the main body of the report.

NASA/CR-2016-xxxxxx

• NASA Low Boom Flight Demonstrator Community Response Pre-Test

Armstrong Flight Research Center May 8-12, 2017

Robert P. Hunte - Applied Physical Sciences Corp.

Kathleen K. Hodgdon - Penn State University, Applied Research Lab

Juliet A. Page - Volpe National Transportation Systems Center, US DOT

Robert A. Cowart - Gulfstream Aerospace

Domenic J. Maglieri - Eagle Aeronautics

Kevin A. Bradley - KBR Wyle

Trent A. Gaugler - Gaugler Consulting

Prepared for

Contract NNL15AA00C

Alexandra Loubeau (Ph.D.)

Hampton, VA, July 9, 2017

NASA STI Program ... in Profile

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  Mail Stop 148

  NASA Langley Research Center

  Hampton, VA 23681-2199

NASA/CONTRACTOR REPORT-2016–xxxxxx

NASA Low Boom Flight Demonstrator Community Response Pre-Test Armstrong Flight Research Center May 8-12, 2017

Waveform and Sonic Boom Perception and Response Risk Reduction (WSPRRR)

Robert P. Hunte - Applied Physical Sciences Corp.

Kathleen K. Hodgdon - Penn State University, Applied Research Lab

Juliet A. Page - Volpe National Transportation Research Center

Robert A. Cowart - Gulfstream Aerospace

Domenic J. Maglieri - Eagle Aeronautics

Kevin A. Bradley - KBR Wyle

Trent A. Gaugler - Gaugler Consulting

Prepared for

Contract NNL15AA00C

Alexandra Loubeau (Ph.D.)

Hampton, VA, July 9, 2017

July 2017

Acknowledgments

Alexandra Loubeau, NASA LaRC Technical Monitor

Larry J. Cliatt, II, NASA AFRC Point of Contact

This report is available in electronic form at http://

Table of Contents

Figures

Tables

1. Executive Summary

Phase 1 of this effort, completed in June 2016, identified and prioritized significant risks associated with a Community Response Test of the Quiet Supersonic Transport (QueSST) experimental aircraft (Figure 1). Significant risks identified in Phase 1 and addressed in the AFRC Pre-Test included:

- #27 Participant location determination – Our approach is based on being able to correlate a subjective response to measurements of the sonic boom that the participant was responding to. We have sought to establish methods to determine the participant's location at the time of the sonic boom.
- #23 No Subjective Response – The boom expected to be delivered by the QueSST aircraft is anticipated to be far less than traditional sonic booms as delivered by the Concorde Supersonic Transport or military aircraft, therefore we need to explore methods to determine whether "no subject response" is because they didn't hear the aircraft or they heard it but weren't bothered enough to respond.
- #8 Noise Monitoring Across a Large Carpet Region – A principle of our approach is that it is not enough to measure subjective response data but that we need to have an accurate measurement of the sonic boom which was the cause of that response. The boom carpet anticipated for the QueSST aircraft could range across 2000 square miles; this will require a network of remotely controlled noise monitors distributed through multiple communities.

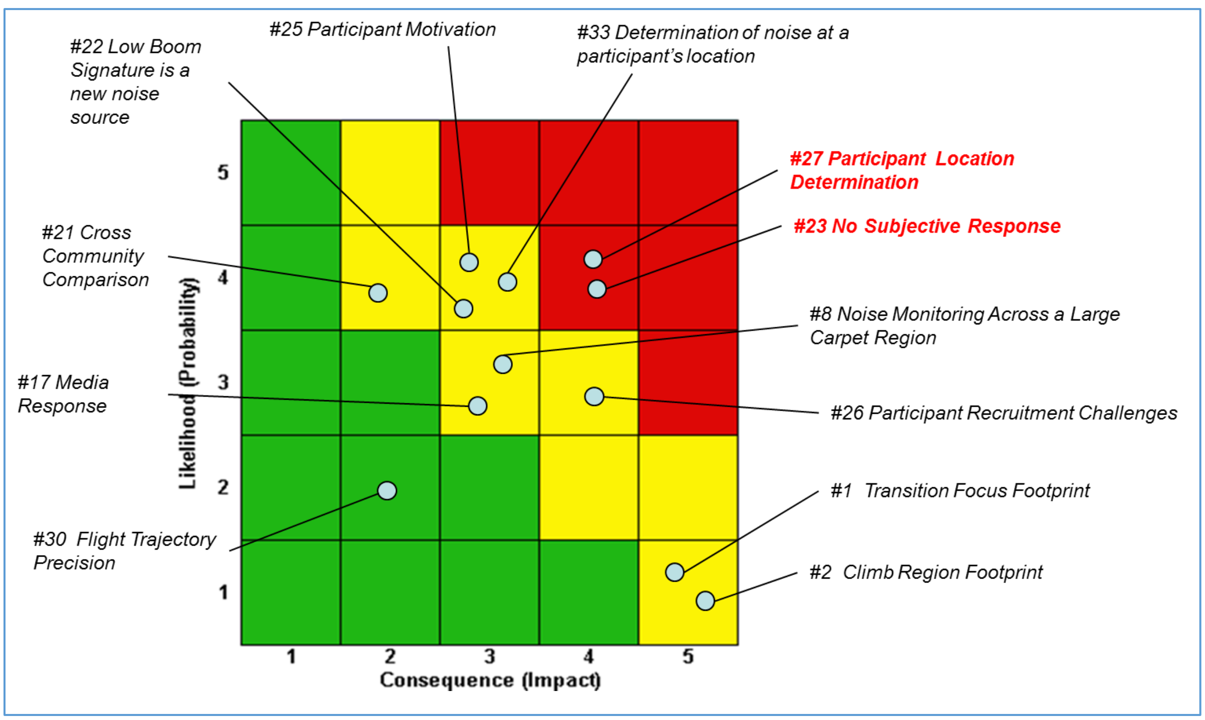


Figure 1 WSPRRR Phase 1 Summary of Significant Risks

The AFRC Community Response Test was a conducted from 8-12 May 2017. The intent of this test was to evaluate mitigation methods for these risks; specifically to (1) explore the accuracy with which we would be able to determine the location of a subjective response from a participant at the time of a sonic boom event; (2) to determine the effectiveness of our subjective survey methods, and (3) to determine the effectiveness of our cellular networking of acoustic data collection equipment across the full extent of the sonic boom footprint.

These tests were also designed to provide for Lessons Learned regarding the control and placement of the boom footprint from the Low Boom Dive Maneuver (LBDM) within the test control area containing the ground acoustic array and test subjects, communications, instrumentation setup and operation, time to setup, etc. The event overall was successful in that it provided valuable lessons learned and validated key data collection methods planned for the risk reduction Community Response Test scheduled for September 2018.

Over the course of the three days 9 flights were executed with 21 booms delivered in the vicinity of 41 potential participants resulting in 252 boom recordings collected and the opportunity for collection of 861 responses (if every recruit participated and every participant responded to every boom). Participants received random text messages during the course of the day to remind them to be attentive for Sonic Booms. There were in fact 145 Single Event survey responses: 79 responses from WSPRRR Team Members, 2 responses where the ID was unknown, and 64 responses from AFRC participants.

2. WSPRRR AFRC News Articles

The Antelope Valley Times (http://theavtimes.com/2017/05/05/nasa-flights-to-study-methods-for-future-sonic-boom-community-response-testing/) ran a story on 5 May 2017 prior to the start of the test as did the Antelope Valley Press. The articles are inserted below:

NASA flights to study methods for future sonic boom community response testing

by The AV Times Staff May 5, 2017 4 Comments

EDWARDS – NASA is set to begin a series of flights at Edwards Air Force Base to investigate the use of cell phone technology to perform community response testing of low sonic Booms.

The Waveforms and Sonic boom Perception and Response Risk Reduction, or WSPRRR, flights will be flown out of NASA's Armstrong Flight Research Center, located at Edwards. Flights are expected to begin on Tuesday, May 9, and will continue for approximately three days, with expected conclusion of the series on either Thursday, May 11, or Friday, May 12.

During this period, a number of sonic booms may be heard throughout Edwards, Boron, California City, and Rosamond.

As many as 12 sonic booms, produced over three-to-four total flights each day, may be heard per day. NASA will fly an F-18 aircraft to produce the booms, which are expected to be separated by 20 to 30 minutes between sonic booms.

The WSPRRR flights will also allow NASA researchers to validate technology and equipment used to measure sonic booms on the ground. NASA's Commercial Supersonic Technology project is validating methods and technology that will allow communities to provide quick, precise feedback to NASA during the future community response phase of the proposed Low Boom Flight Demonstrator, or LBFD. The objective of LBFD will be to demonstrate supersonic flight that lowers the volume and perceived magnitude of the sonic boom, associated with supersonic flight, to a soft "thump."

NASA's Aeronautics Research Mission Directorate's supersonic research will assist the Federal Aviation Administration to identify and develop noise standards for potential future supersonic flight overland.

Employees of NASA Armstrong, volunteering to take part in the study, will be providing the feedback digitally, in order to validate community response methods. Data from the research study will help NASA refine testing procedures to understand the impact of sonic booms on communities.

For more information about NASA's Commercial Supersonic Technology project, visit: https://www.nasa.gov/subject/7566/supersonic-flight/.

The public was aware that the test was going to be conducted as reflected in the article from the Antelope Valley Press provided by a friend of Domenic Maglieri (Figure 2).

For details, call (661) 822-0412. through Thursday.

Booms to batter AV this week

Valley Press

EDWARDS AFB — Antelope Valley residents can expect to hear up to a dozen sonic booms a day this week as NASA begins a series of flights to test the use of cellphone technology to measure community response to low-intensity sonic booms.

The flights, from Armstrong Flight Research Center at Edwards Air Force Base, are expected to begin Tuesday and continue for approximately three days, concluding either Thursday or Friday. The sonic booms are expected to be most audible at Edwards, Boron, California City and Rosamond.

As many as 12 sonic booms each day will be produced during three to four daily flights by a NASA F-18 fighter jet. The sonic booms will likely be spaced about 20 to 30 minutes apart, officials said.

Employees of NASA Armstrong, volunteering to take part in the study, will be providing the feedback digitally, in order to validate community response methods. Data from the research study will help NASA refine testing procedures to understand the impact of sonic booms on communitie, officials said.

The tests are part of the Waveforms and Sonic boom Perception and Response Risk Reduction, or WSPRRR, project, part of an

See BOOMS on A5

NASA

LOOK OUT BELOW — A NASA Armstrong Flight Research Center F/A-18 jet will be used to create sonic booms over the Antelope Valley in a test program expected to start Tuesday.

BOOMS

From A1

overall agency program to develop supersonic aircraft capable of flying over populated areas without creating sonic booms that disturb people on the ground.

This part of the program allows researchers to validate technology and equipment used to measure sonic booms on the ground. Such technology and methods will be used as part of NASA's Commercial Supersonic Technology program to allow communities to provide quick, precise feedback to NASA during a future phase of the proposed Low Boom Flight Demonstrator project.

That project is intended to demonstrate supersonic flight that lowers the volume and perceived impact of sonic booms, so that they amount to a soft "thump" to people on the ground.

NASA's Aeronautics Research Mission Directorate's supersonic research will assist the Federal Aviation Administration to identify and develop noise standards for potential future supersonic flight overland.

NASA is working with Applied Physical Sciences Corp. of Groton, Connecticut; Pennsylvania State University; Eagle Aeronautics of Newport, Virginia; Gaugler Consulting of Eason, Pennsylvania; Gulfstream Aerospace of Savannah, Georgia; Volpe National Transportation Systems Center of Cambridge, Massachusetts, and KBR Wyle of El Segundo to conduct the tests.

To share your opinion on this article or any other article, write a letter to the editor and email it to editor@avpress.com or mail it to Letters to Editor, PO Box 4050, Palmdale, CA 93590-4050.

Figure 2 Antelope Valley Press 5 May 2017

3. Daily Operations

3.1 Monday May 8th

The APS WSPRRR Team consisting of Robert Hunte (APS), Juliet Page (Volpe), Kelsey Huyghebaert (APS), and Matt Collmar (GSA) had arrived on Sunday May 7th, checked into EAFB visitor control at 0730, and AFRC visitor control at 0830 on Monday May 8th. The team gained access to their equipment, previously shipped on 28 April.

Equipment was inventoried and assembled within the Building 4840 Hanger Bay. Cellular connectivity was verified between the base station and each of the SBUDAS noise monitors.

A full team coordination meeting was conducted at 1300. LMR radios were provided to the APS WSPRRR team members by NASA AFRC.

The base station was then relocated to the vicinity of the Control Room where it was originally planned to reside during flight operations. A complete calibration of all six SBUDAS (located just outside Hanger Bay Building 4840) from the base station (located just outside the control room) was then accomplished.

With the base station remaining in the vicinity of the Control Room, connectivity was then verified with each of the SBUDAS noise monitors at the position where it was to be deployed for flight operations as shown in Figure 3. The cluster of colored dots represent the positions of noise monitor placement during WSPR 2011. It can be seen in Figure 4 that for this event the sonic boom measurements are being made across a significantly wider area covering a greater extent of the sonic boom footprint.

Figure 3 Noise Monitor Deployment positions. Six SBUDAS were deployed daily and operated by the APS Team while 4 SPIKE were deployed and operated by AFRC personnel. On the final day of the event SBUDAS DELTA was co-located with a SPIKE unit for comparison of measurements to support evaluation of integration of both types of units during the planned Community Response Test. The colored dots in the left portion represent WSPR 2011 sensor placement.

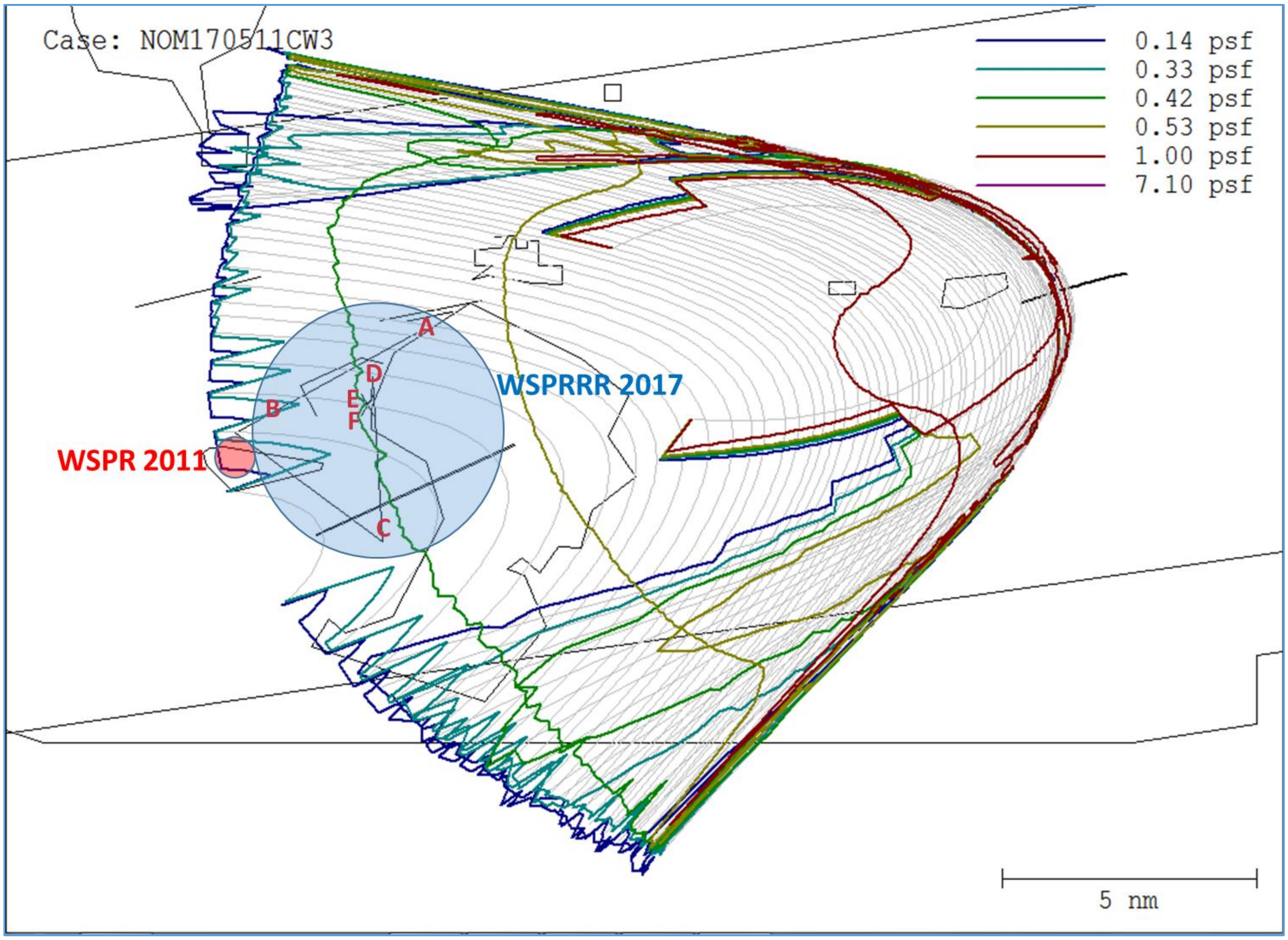


Figure 4 Approximate positions of SBUDAS monitors across predicted sonic boom footprint contrasting area measured during the AFRC Pre-Test as compared to WSPR 2011

All SBUDAS were deployed daily and removed on the completion of flights for the day. NASA weather towers were additionally deployed in the vicinity of SBUDAS Alpha and Charlie with data downloaded daily.

Ed Haering (AFRC) calculated LBDM waypoints based on modelled atmospheric forecast data. Waypoints are shown for each day in Appendix B.

Kathy Hodgdon (ARL Penn State) supported subjective data collection on a daily basis, operating remotely from ARL Penn State with support from the Penn State Survey Research Center (SRC).

There were some last minute adjustments made to the recruitment and survey website due to edits and recommendations made by members of the WSPRRR team and by the NASA Public Affairs Office. An issue was observed when the initial emails from SRC going to potential recruits ended up going to the receivers spam or junk email boxes. To address this issue the recruit emails were sent from a PSU outgoing address to ensure delivery.

Texts messages were sent via Google voice, a free service used to send text messages. The process involved sending individual text messages, 1 by 1, to each of the participants. While this was somewhat laborious, it worked well with a smaller participant list. This would not work with a much larger sample size. While this system is somewhat reliable, there were times that a “message not received” warning was shown. The text message summary is presented in the Appendix E.

To address a larger sample size and the potential for missed messages, the SRC has been looking at the SMS feature in Qualtrics. At the time of the study, this feature was not fully activated in Qualtrics, but it has been activated since. While this feature is mainly intended to send or receive survey questions, it can be used to send announcements. This service is a paid feature in Qualtrics. There is another service that the SRC has not tested, it is called “survey signal.” This is another paid service that is more expensive than Qualtrics, but the main intention is to send notifications and announcements. The SRC will investigate best options prior to the community test.

The SRC contacted all of the individuals that completed the recruitment survey on Monday May 8th, just before the start of the field test. It was anticipated that the recruits would be contacted immediately after they signed up in the week prior to the test. The SRC indicated it was their standard practice to contact all recruits the day before the test, to remind them that the start of the test was imminent. The community test has a different recruitment process than the AFRC test, so this issue will not be applicable for the community test.

3.2 Tuesday May 9th

Three flights were planned for this day to deliver 8 booms. Ultimately 5 booms were executed and recorded by SBUDAS as detailed below.

SBUDAS deployment began at 0430. The equipment was divided between three vehicles: Bob Hunte (APS) had SBUDAS Alpha and Delta, Kelsey Huyghebaert (APS) had SBUDAS Bravo and Charlie while the microphones and electronics enclosures for SBUDAS Echo and Foxtrot were in a NASA van within the AFRC secure perimeter. Echo and Foxtrot were initially installed each day by Larry Cliatt (AFRC) and Juliet Page (Volpe). Matt Collmar (Gulfstream) manned the Base Station and initiated control of all SBUDAS as they were deployed. Upon deployment it was found that the GRAS power supply needed to be replaced on SBUDAS Bravo and that channel 2 of SBUDAS Foxtrot was inoperable. All SBUDAS were confirmed on line and calibrated as of 0700 (first flight scheduled for 0800).

Flight waypoints and predicted boom footprints were calculated by Ed Haering based on updated weather data as shown Appendix B.

The first flight took off at 0800 delivering the first boom at 0812 and the second boom at 0851 local time. The first boom was recorded by all SBUDAS. Initial overpressure (PSF) levels as recorded by SBUDAS for the first boom are reflected in Table 1:

Table 1 Flight 01 Pass01

Noise Monitor	PSF Channel 1
Alpha	.168
Bravo	
Charlie	.112
Delta	.139
Echo	.046
Foxtrot	.150

Following the recording of the second boom the base station experienced excessive latency in connection and response with all SBUDAS. In the field, R. Hunte was able to login to all modems through a cell phone browser and was able to verify that all modems were on line with good to excellent signal strength. This problem in connectivity caused us to cancel the third pass for the 0800 flight and ultimately to cancel the 1100 flight as we did not have SBUDAS connectivity necessary to satisfy "Go-No Go" criteria. The base station was then re-located in Larry Cliatt's office (removed from the vicinity of the command center) where cellular connectivity was restored, all SBUDAS were calibrated and "Go-No Go" criteria was satisfied by 1200 allowing the next flight to takeoff at 1330 local time. The reason for the initial loss of connectivity cannot be conclusively identified, though contributing factors identified include:

- A Verizon network was installed in the building where the base station was located. This network consisted of a number of cellular network "repeaters" located throughout the building and relocating the base station allowed it to connect with a less burdened repeater.
- Network services for telnet, ssh, http and https were not disabled on all of the cellular modems associated with the base station and the SBUDAS noise monitors, a review of the cellular logs indicated a number of unknown IP addresses which were attempting to gain access to the modems. Non-vital network services for all cellular modems were disabled on Monday evening.

The predicted footprint for afternoon flights before 1430 local time are shown in Appendix BII.

Three booms were delivered from this flight at 1316, 1339, and 1359 local time. All were recorded successfully by all SBUDAS.

A third flight on Tuesday was cancelled as rain showers moved into the area and all SBUDAS and SPIKEs were secured to avoid damage due to rain.

3.3 Wednesday, May 10th

There were four flights scheduled for this day with for a total of 10 booms for the day.

All SBUDAS were deployed and calibrated as of 0700 local time.   Ed Haering calculated waypoints and provided PCBoom predictions as shown in Appendix BIII.

The first boom was delivered at 0811 with initial overpressure levels as reflected in Table 2.

Table 2 Flight 03 Pass 01

Noise Monitor	PSF Channel 1	PSF Channel 2
Alpha	0.759	0.760
Bravo	0.307	0.310
Charlie	0.457	0.448
Delta	0.651	0.648
Echo	0.566	0.568
Foxtrot	0.617	-----

The second boom was delivered at 0837 with initial overpressure levels as reflected in Table 3.

Table 3 Flight 03 Pass 02

Noise Monitor	PSF Channel 1	PSF Channel 2
Alpha	0.193	0.203
Bravo	0.068	0.064
Charlie	0.154	0.152
Delta	0.184	0.184
Echo	0.129	0.124
Foxtrot	0.167	----

The third boom was delivered at 0902 with initial overpressure levels as reflected in Table 4.

Table 4 Flight 03 Pass 03

Noise Monitor	PSF Channel 1	PSF Channel 2
Alpha	0.192	0.185
Bravo	0.062	0.065
Charlie	0.129	0.137
Delta	0.137	0.135
Echo	0.096	0.072
Foxtrot	0.079	----

Following this flight all SBUDAS were calibrated.

WSPRRR Flight #4 was airborne at 1013. The boom was delivered at 1025, with initial overpressure levels recorded as shown in Table 5.

Table 5 Flight 04 Pass 01

Noise Monitor	PSF Channel 1	PSF Channel 2
Alpha	0.817	0.844
Bravo	0.612	0.621
Charlie	0.053	0.065
Delta	0.520	0.509
Echo	0.751	0.752
Foxtrot	0.625	----

The low level of 0.053 psf at Charlie was initially a source of concern however it was verified during the second boom that in fact Charlie was positioned on the edge of the footprint as shown in Figure 5.

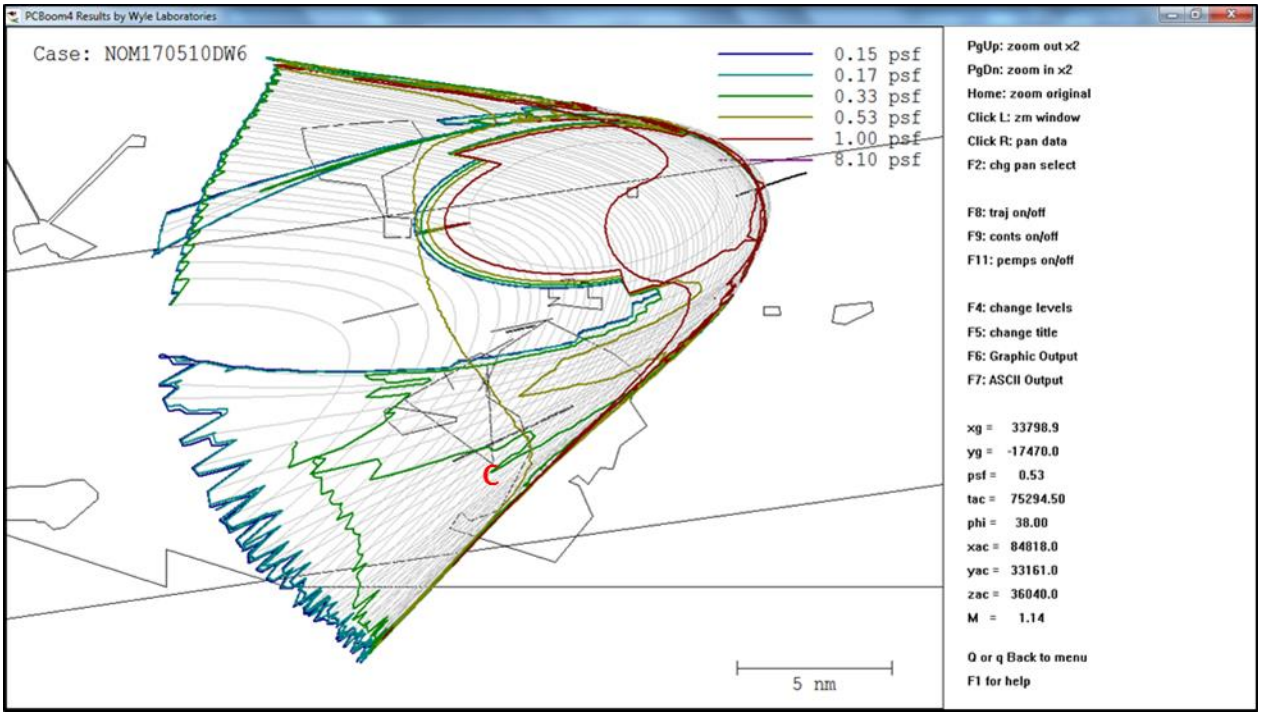


Figure 5 ***For booms between 10:30AM and 11:30AM local time:*** *m17051018z06forecast.atm weather file nom170510dw6F-18 Dive Point 35 04' 12"N, 117 46' 44"W 2388 Grnd 34:57:04 -117:53:14 105 0.53*

As seen in Figure 6, overpressure at each of the SBUDAS was significantly higher than that measured at Charlie. Figure 7 shows an enlarged view on the same time scale of the overpressure recorded at Alpha as opposed to that measured at Charlie.

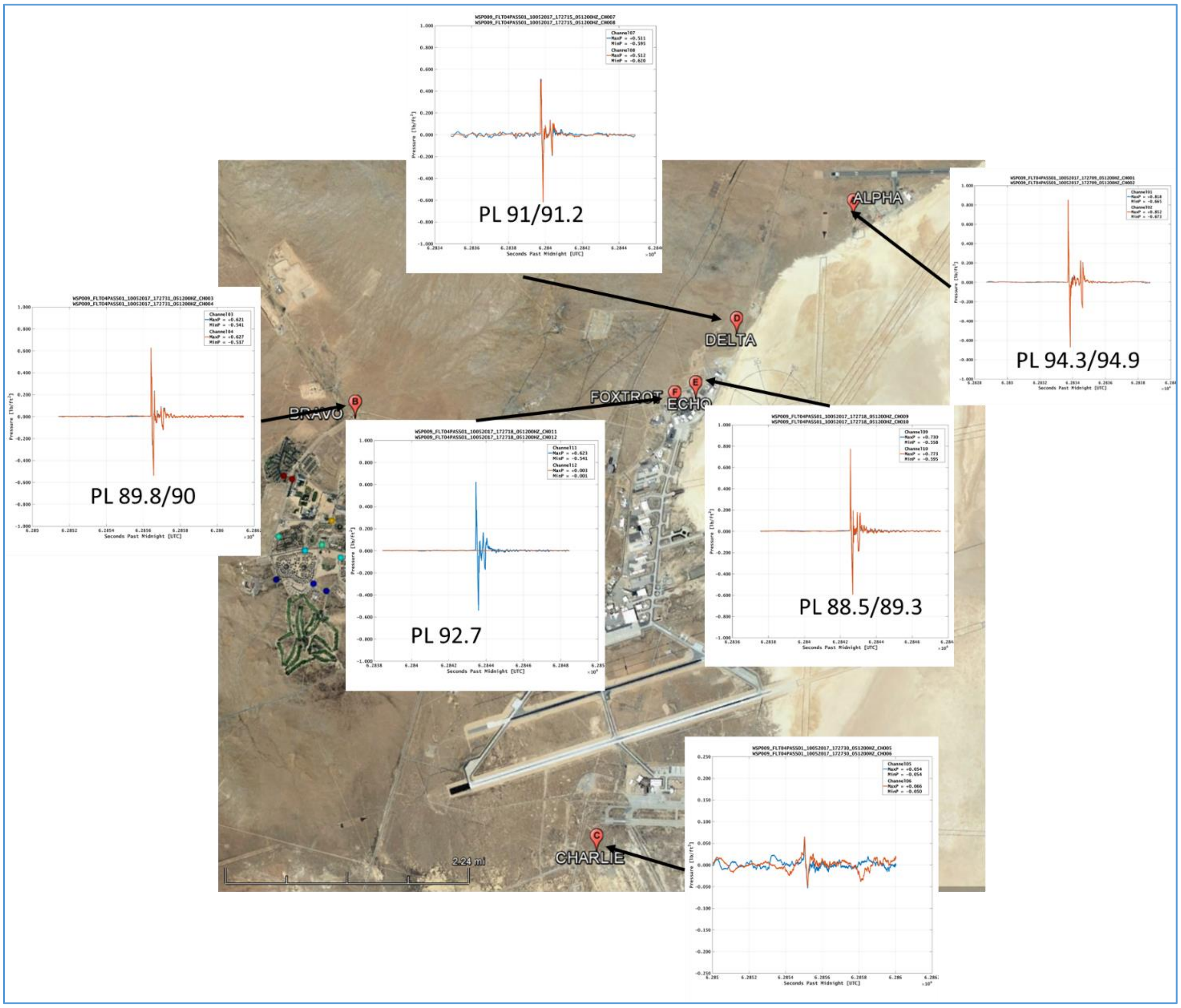


Figure 6 Delta P and PL measurements obtained at each SBUDAS for Flight 04 Pass 01

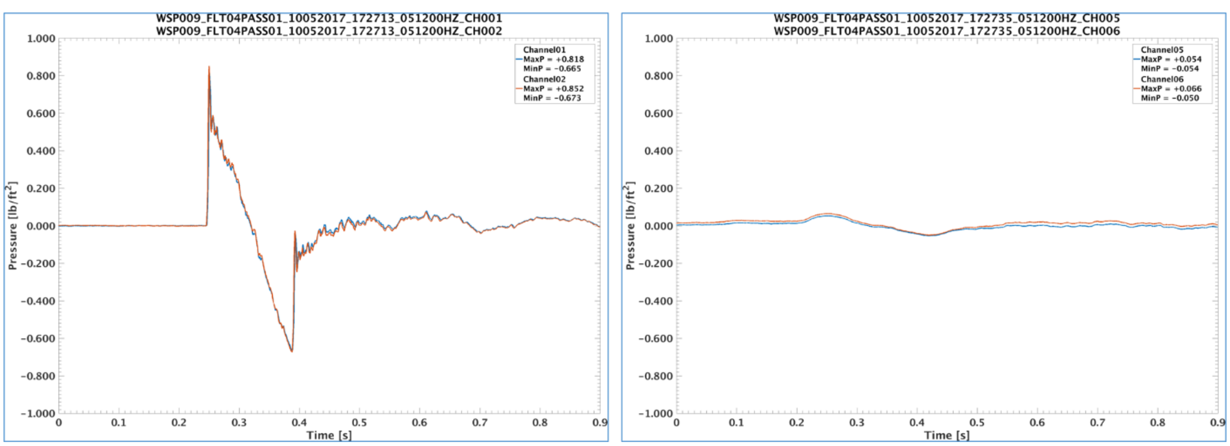


Figure 7 SBUDAS Alpha (left) with SBUDAS Charlie (right) for Flight 04 Pass01

At 1038 cellular connectivity experienced an interruption which delayed the next LBDM. SBUDAS connectivity was re-established by 1054 allowing the second boom to be delivered at 1102 and the third 1120. All SBUDAS were operational and recording, though it was confirmed by Kelsey Huyghebaert that nothing was heard at Charlie. Following the second boom at 1120 all SBUDAS were calibrated prior to the next flight.

WSPRRR Flight #5 was airborne at 1200 with the LBDM executed at 1215 and a second executed at 1301. PCBoom predictions for this flight are reflected in Appendix BIII.

Initial overpressure levels recorded are shown in Table 6 for the LBDM executed at 1215. The second boom was recorded by all SBUDAS though it was barely audible to Kelsey Huyghebaert at Charlie. All SBUDAS were calibrated once again prior to the next flight.

Table 6 Flight 05 Pass01

Noise Monitor	PSF Channel 1	PSF Channel 2
Alpha	0.764	0.791
Bravo	0.460	0.461
Charlie	0.0004	0.039
Delta	0.634	0.646
Echo	-----	-----
Foxtrot	-----	-----

WSPRRR Flight #6 was airborne at 1355 with the first LBDM executed at 1408 and a second boom at 1449.

PCBoom predictions for this flight are reflected in Appendix BIII.

Initial overpressure recordings at all SBUDAS for the boom delivered at 1408 are reflected in Table 7.

Table 7 Flight 06 Pass01

Noise Monitor	PSF Channel 1	PSF Channel 2
Alpha	0.721	0.722
Bravo	0.405	0.400
Charlie	0.066	0.066
Delta	0.560	0.576
Echo	0.791	0.854
Foxtrot	0.636	-----

During this flight LMR communications began to become difficult, personnel at site Alpha were able to hear but could not be heard by personnel at Charlie or the Base Station, so personnel at Spike 2 began to act as a relay.

Measurements collected during the second pass of Flight 06 executed at 1449 are reflected in Figure 8.

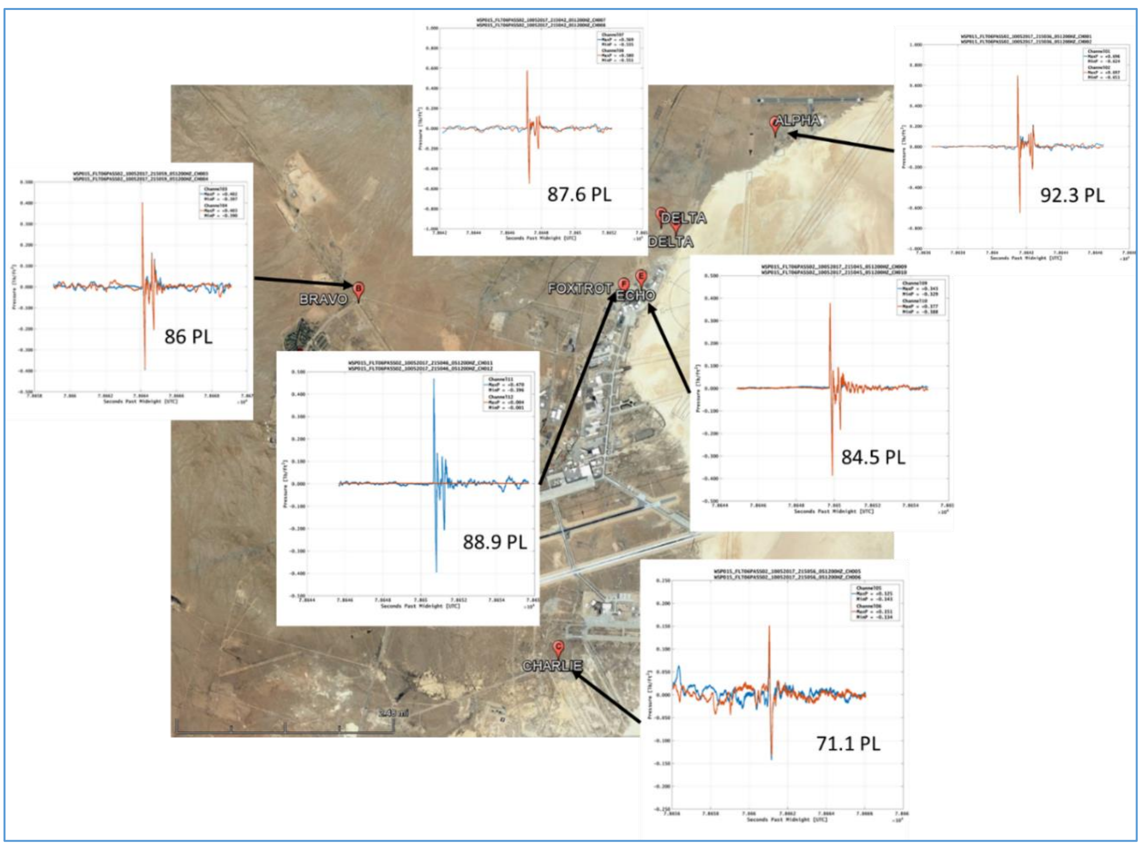


Figure 8 Delta P and PL as measured at each SBUDAS for Flight 06 Pass 02 executed on 10 May 2017 at 1449 local time

3.4 Thursday May 11th

There were three flights scheduled for this day, delivering a total of six booms. On this day SBUDAS Delta was relocated ~0.2 miles to the North and collocated with an additional SPIKE unit made available by AFRC. This was done to support better comparison of the signature recordings by the two types of noise monitors. SPIKE 5 was operated by Bob Hunte (APS). All SBUDAS were on line and calibrated by 0637. Ambient noise noted on this day was a power washer being operated 200 yards south of Charlie and also C-17 take off at 0944, additionally it was noted by the Base Station Operator that ambient noise was noted at Bravo and Foxtrot during the first boom of the day. Six booms over the course of three flights were delivered and recorded for the day. The first Boom was scheduled to occur at 0815 with 0.18 psf with a second boom to occur at 0900 with 0.33 sf. Initial overpressure readings noted on the base station for the first boom at 0815 are noted in Table 8. A non-WSPRRR boom was noted at 0901, it is not clear if this was recorded.

Table 8 Flight 08 Pass01

Noise Monitor	PSF Channel 1	PSF Channel 2
Alpha	0.087	0.045
Bravo	0.026	0.026
Charlie	0.050	0.052
Delta	0.076	0.070
Echo	0.259	0.048
Foxtrot	0.052	-----

4. Acoustic Data Collection

In total we collected 252 acoustic files from the 21 sonic booms delivered. Of these, 171 acoustic files were selected for processing. Non selection of files could be attributed to: No measurable signal, calibration differences exceeding 0.5dB, excessive signal noise, or significant differences between channels.

4.1 Acoustic Data Processing

Each noise file was examined by the “Auto Boom Finder,” produced following WSPR 2011. This algorithm looks for the presence of anything that it thinks is a boom using a combination of the PADS trigger algorithm (NASA) and a spectral check included to look for the unique character of the Low Boom Diver Maneuver booms. Modifications to this program since WSPR 2011 include changes to the FFT routine to double precision to avoid a problem when working with really low booms and how it determines whether the boom is above ambient. It now uses a more aggressive method to recover the individual one-third octave bands that are below the ambient. Previous work by NASA rejected booms who's ASEL was within 1 dBA of the ambient. For WSPR 2011 the ambient spectra was subtracted from the boom (1st – Ambient) in order to calculate metrics for more of the data set. The input parameters of the trigger routine had to be adjusted to find some of the very small booms that were recorded. Many noise events were not booms and the metrics were not calculated. This occurred at the edges of the carpet. The association of data channels to noise monitors is as shown in Table 9.

Table 9 Channels assignments by SPUDAS Monitor

ALPHA	Channel 1 and Channel 2
BRAVO	Channel 3 and Channel 4
CHARLIE	Channel 5 and Channel 6
DELTA	Channels 7,8,13,14 (Delta is noted as four channels as its location was adjusted on the last day of the event to support comparisons with SPIKE equipment)
ECHO	Chanel 9 and Channel 10
FOXTROT	Channel 11 (Channel 12 was not functioning)

Ambient noise associated with each boom was calculated from a 650ms window preceding the boom. The front shock of the boom was typically 250ms into a window that is 650ms long. Metrics calculated are shown in Table 10.

Table 10 AFRC Pre-Test Acoustic Metrics

Metric	Unit	Description
PL	dB	Steven's Mark VII Perceived Level
CSEL	dB	C-weighted Sound Exposure Level
ASEL	dB	A-weighted Sound Exposure Level
FSEL	dB	Unweighted Sound Exposure Level
LLZf	Phons	Zwicker loudness for frontal incidence
LLZd	Phons	Zwicker loudness for diffuse incidence
PNL	dB	Kryter's Perceived Noise Level
BSEL	dB	B-weighted Sound Exposure Level
DSEL	dB	D-weighted Sound Exposure Level
ESEL	dB	E-weighted Sound Exposure Level
ISBAP	dB	Indoor Sonic Boom Annoyance Prediction Level

Over the course of the 3 days of flight tests variability in the booms recorded at each of the SBUDAS locations was experienced as a result of changing atmospheric conditions and the slight variations in performing the Low Boom Dive Maneuver. The results presented in Table 11 indicate the range of variability in the measured overpressures and calculated perceived levels experienced at each SBUDAS for the 21 boom passes.

The maximum and minimum boom levels were 1.05 psf and 0.05 psf respectively, with an average values in the 0.30-0.40 psf range which is within the 0.30 psf target for the Low Boom Demonstrator (LBFD). The average PL's however are on the high side of the LBFD target of 75 dB because the boom signatures are more N-wave in shape having small shock rise times compared to the low boom shaped signature of the LBFD. Delta was relocated approximately 200 yards north on the last day of the event for comparison with SPIKE measurements and is listed as DELTA-1 in Table 11.

Table 11 Tabulation of the minimum, maximum, average, and standard deviation of the measured overpressures and calculated perceived levels observed at each SBUDAS location for the 21 booms from 9 flights over the course of 3 days. DELTA was relocated on the last day of the event for comparison with SPIKE measurements and is listed at DELTA-1.

	ΔP,psf				PL, dB			
	Min	Max	Average	Std Dev	Min	Max	Average	Std Dev
ALPHA	0.09	1.05	0.59	0.28	63.10	97.90	86.41	9.55
BRAVO	0.08	0.74	0.38	0.18	61.40	91.00	80.52	8.46
CHARLIE	0.05	0.46	0.24	0.12	61.30	87.70	73.99	7.14
DELTA	0.10	0.68	0.45	0.20	63.00	93.50	83.04	9.63
DELTA-1	0.19	0.39	0.30	0.07	68	80.4	77.06	4.60
ECHO	0.07	0.93	0.39	0.25	62.80	94.50	81.02	9.10
FOXTROT	0.08	0.89	0.40	0.23	69.40	93.10	83.77	7.36

The first boom was processed in a 650 ms window as per the method specified by NASA and reiterated in the WSPR 2011 data report. Starting from the same point in the recording, a 2 second window was analyzed as shown in Figure 9. The 2 second window was analyzed in that this would include the second boom and whatever additional energy is in the ambient. The third data set is a plot of the loudness calculated from the 650 ms boom spectrum after subtracting the previous 650 ms ambient spectrum. The missing points on the left are because the boom spectrum is not always above the ambient.

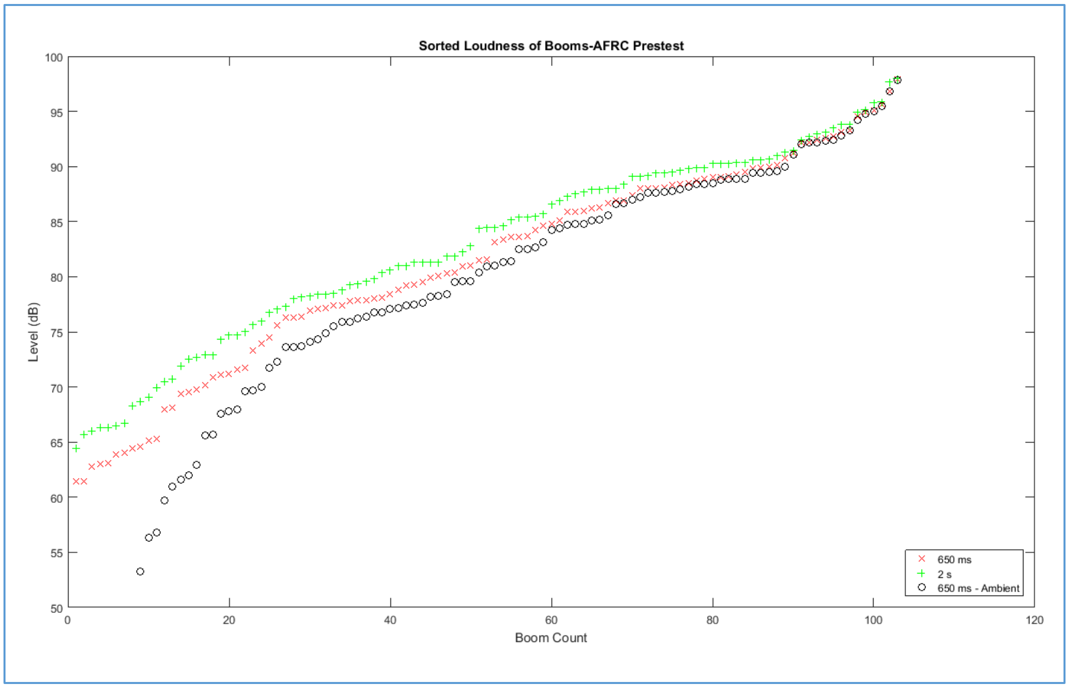


Figure 9 Sorted Loudness of Sonic Booms collected during the AFRC Pre-test as measured in Stevens Mark VII Loudness (PL)

During the pre-test there were significant sources of ambient noise (operating in the vicinity of EAFB). For several booms there were aircraft overhead or running up engines on the runway, several trains passed to the North, and there was a jack hammer operating in the vicinity of Bravo.

5. Subjective Response Summary

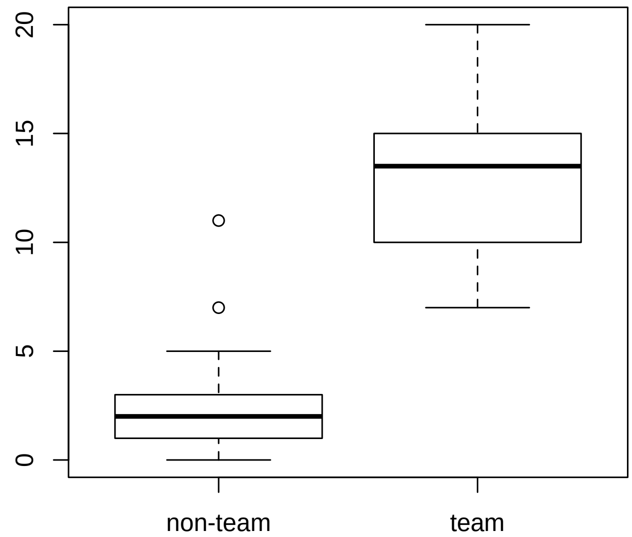
Participants completed a recruitment survey, a background survey, single event surveys in response to individual boom events, daily summary surveys, and a final feedback survey. The recruitment survey was implemented to ensure that individuals were eligible to be participants. The SRC contacted all participants the day before the flights started to confirm their enrollment in the study. The background survey included demographics and attitudes, as well as the street address or building where they spent most of their day at work. The address was requested as an alternate method to identify their work location. The single event survey gathered responses to individual boom events. The daily summary survey gathered a summary of their daily annoyance response and can be used in conjunction with the single event survey to verify how many booms each respondent noticed on each day. The final feedback was administered to afford participants the opportunity to provide comments and insights on the test process.

There were 41 participant numbers assigned to potential recruits, 7 of which were team members. Of those 41, only 31 completed background surveys. Of those 31, 6 were team members and 25 were non-team members. Over the three day test period, there were 21 booms in the vicinity of 41 participants resulting in the opportunity for collection of 861 responses (if all 41 recruits participated and every participant responded to every boom). Participants received random text messages during the course of the day to remind them to be attentive for Sonic Booms. There were in fact 145 Single Event survey responses: 79 responses from WSPRRR Team Members, 2 responses where the ID was unknown, and 64 responses from AFRC participants.

For the Daily summary 5 of the 6 team members responded on 5/9 and 5/10, and all 6 responded on 5/11. For the non-team member response to the Daily summary, only 12 of the 25 non-team members responded on 5/9 and 5/10, and only 11 of the 25 non-team members responded on 5/11. We will add a text prompt to remind participants to complete the Daily Summary. The feedback survey was completed by only 4 team members and 3 recruits. They all indicated that the text notifications were helpful. The geo-location and survey response instruments were rated for ease of use. One individual indicated that they were slightly easy to use, three individuals indicated that they were moderately easy to use, and three individuals indicated that they were very easy to use. Their comments are provided in Appendix D. A preliminary overview of the single event response data is presented below.

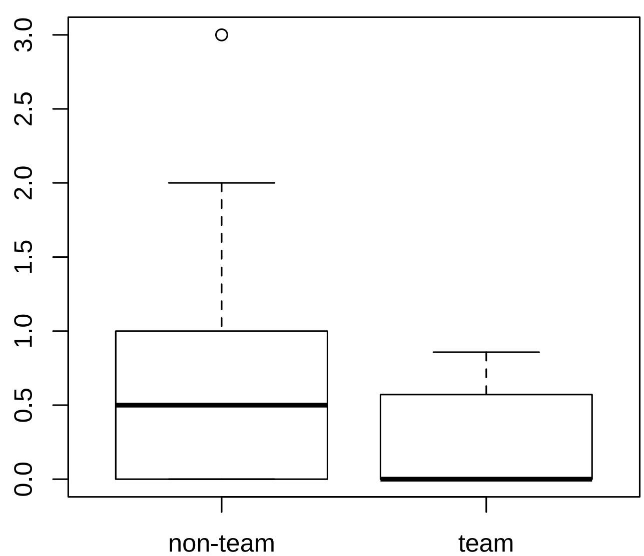
5.1 Single Event Response Rates

For single event responses, the following boxplot shows how the team members responded much more frequently to the events. The team members had an average total number of single event responses of 13.17 (median 13.5) over a range from 7 to 20, whereas for the non-team members, the average was only 2.52 (median 2) over a range from 0 to 11.

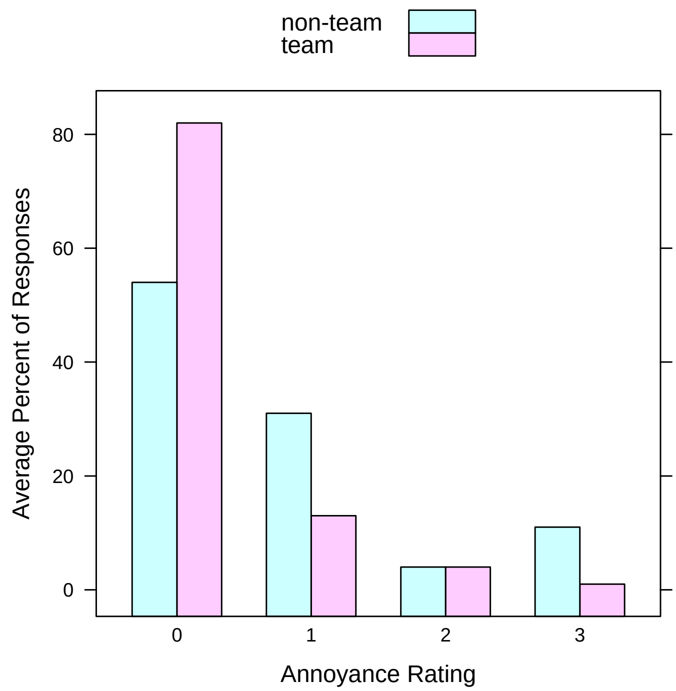


Single Event Annoyance Responses

For single event responses, the following boxplot shows how the team members responded with less annoyance to the events than the non-team members. Here, all ratings of single events were averaged on the 6-point annoyance scale (from 0-5) for each respondent. The team members had an average annoyance of 0.24 (median 0) over a range from 0 to .86, whereas for the non-team members, the average was .63 (median .5) over a range from 0 to 3. It should be noted that the raw responses ranged from 0 to 3, as nobody utilized the highest two ratings for annoyance. The one person with an average annoyance of 3 only rated one event.



Further, the percentage of times respondents gave the events each annoyance rating were recorded, and averaged for all response categories. The following plot shows how the average percentage of each rating category differs for team and non-team members. Note again that the raw responses ranged from 0 to 3, as nobody utilized the highest two ratings for annoyance.



This was a preliminary overview of the data. The data will be statistically summarized, response rates determined and a full analysis conducted once the noise dose at each participant has been calculated.

For the AFRC data analysis, we plan to treat the team and the recruits as 2 different "communities", one rural, one urban. This affords us the opportunity to test the statistical analysis methods we have proposed for the low boom field test communities. The team members will be treated as a rural community and the recruits will be treated as an urban community. The rationale is that the team members were fewer in numbers, but provided most of the responses, as they were outside, and knew when the booms would occur. This approximated the response anticipated from a more rural community. The recruits were mostly inside, and had no knowledge of when the booms would occur. It is likely that folks did not respond as they didn't hear the boom.

The subjective ratings for annoyance and other categorical attributes, obtained in response to the sonic booms will be gathered from respondents from multiple different communities. There is the potential that the unique characteristics of the ambient noise environments pertinent to the specific communities will affect the ratings. For example, respondents from urban communities may be less likely to hear booms just because they are habituated to a noisier environment, whereas respondents who are from a rural community will be less acclimated to a noisy environment and will be more likely to hear booms, and may be therefore be more prone to annoyance at the new noise source. Ultimately, we want to allow for similarity in ratings due to a shared noise climate.

If we want to account for these differences in our model, we could represent the response of the j[th] person in the i[th] community as:

$$Y_{i,j} = \left(\beta_0 + b_{0,i}\right) + (\beta_1)x_{i,j} + \epsilon_{i,j}.$$

Here, the β_0 and β_1 terms represent the average intercept and slope across communities, while the $b_{0,i}$ term represents deviations from the overall intercept for a specific community, *i*. That is, it might represent the increased annoyance for someone who is not acclimated to noise, or the decreased annoyance for someone who is. As always, we have a random noise term as well, for whatever deviations for which the model is unable to account. This type of model is often referred to as a random intercepts model, and a picture that demonstrates what the model achieves is given in Figure 10 (left).

It should be noted that in a random intercepts model, while we do have a term that accounts for community differences, there is one thing that is consistent across communities. Although they have different intercepts, the functional dependence between the response and the predictor ($x_{i,j}$) is constant; that is, all of the lines in Figure 10 (a) are parallel. If we want to allow the slopes to differ as well, we represent the response of the j[th] person in the i[th] community as:

$$Y_{i,j} = \left(\beta_0 + b_{0,i}\right) + \left(\beta_1 + b_{1,i}\right)x_{i,j} + \epsilon_{i,j}.$$

Again, the β_0 and β_1 terms represent the average intercept and slope across communities, while the $b_{0,i}$ and $b_{1,i}$ terms represent deviations from the overall intercept and slope for a specific community, *i*. This type of model is often referred to as a random slopes model, and a picture that demonstrates what the model achieves is given in Figure 10 (right). Note that here, communities can have a functionally different relationship between annoyance and noise dose.

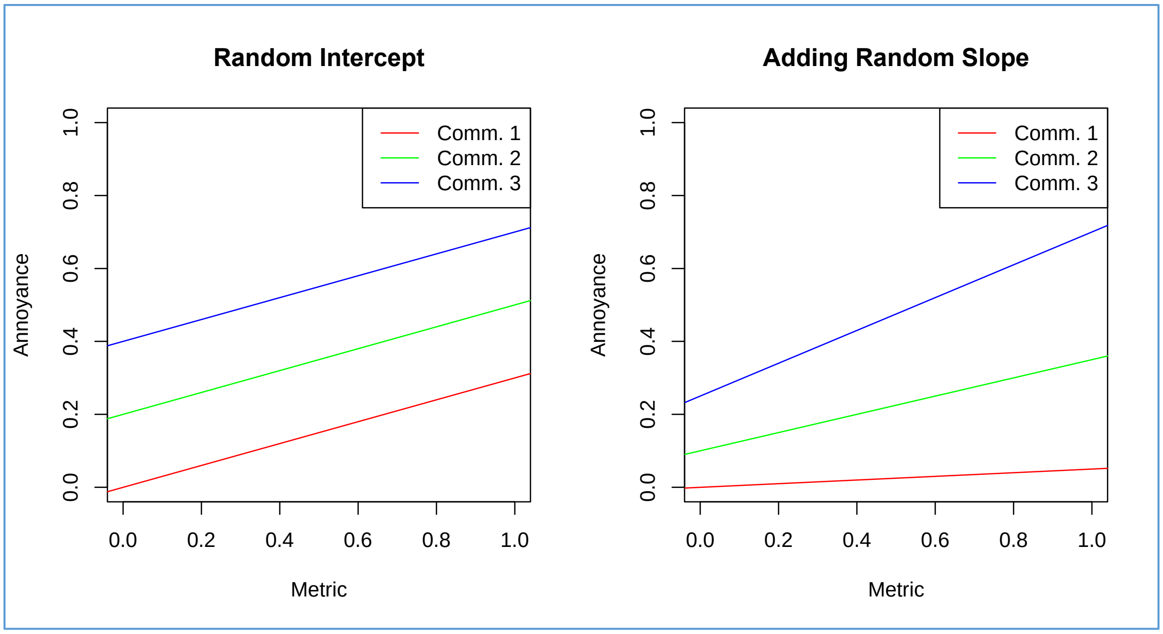


Figure 10 Left (Panel a) Demonstrates Random Intercepts Model; Right (Panel b) Demonstrates Random Slopes Model

5.2 Geolocation

Internet geolocation technology aims to determine the physical geographic location of users and devices. Geolocation is the geographical identification of the location of a person or object, while the word geolocation also refers to the latitude and longitude coordinates of a particular location. Geolocation applications that run on mobile devices provide relevant data that change as your location changes. Smartphones have a GPS chip inside that uses satellite data when the location service is enabled, to calculate your position. When a GPS signal is unavailable, geolocation apps can use information from cell towers to triangulate your approximate position, a method that isn't as accurate as GPS. IP addresses are also used as a mode of geolocation that is employed by internet software. The quality of geolocation results are dependent on the data accuracy, and the time it takes to integrate a given location determines the efficiency of the geolocation process. At a location such as an airport or an active military installation, there may be interference from signals specific to that location that can degrade the ability to automatically get accurate GPS locations. As such, a front end mapping application was designed by the Penn State SRC to query the respondent about their location.

Qualtrics is a web-based tool that can be used to implement on-line surveys, with a feature that provides the latitude and longitude position of a participant responding through the Qualtrics survey app on a GPS-enabled device. As a web-based tool, it relies on the geo-location of the device at the time that the survey link is accessed. If the geo-location services were on, and the device location was already known, then the location provided through the Qualtrics link should be accurate. If the location services were not on, it is conceivable that the device is still accessing the nearest satellite data or cell tower and that the iterative process that refines a location may still be ongoing at the moment that the link is accessed. As such, there may be errors in the location provided through the web-based survey tool.

Risk reduction measures were implemented to address the potential inaccuracy of the automated geolocation of a respondent and to verify their actual location. To determine if the location Qualtrics provides for a survey respondent is correct, The Penn State University Survey Research Center (SRC) developed a simple map-based determination of location. This prototype utilizes a web app developed by Qualtrics™ which provides the latitude and longitude position of a participant responding through the Qualtrics survey app on a GPS-enabled device. A map is displayed and the respondent is prompted to reply if the location displayed is correct or not. If the location is not correct, the respondent can then manually enter their location. As further back up, the respondent provides both their home and work address as points of reference for potential responses.

Participants are going about their daily routines and are busy with their home and work activities as they listen for boom events. This is a realistic scenario that is anticipated, and it is reasonable to expect that respondents may be delayed in submitting their survey response to an individual boom. The respondent is asked “Please provide the nearest street address to where you heard this boom” at the time of their response. They are also asked to provide information on whether they were at or near work or home and whether they were inside or outside one of those locations. The work and home addresses are on file, so that we have multiple reference points as back up methods to ensure an accurate location for their response.

For the AFRC test, 22 of the responses were delayed by more than an hour beyond the reported time of the boom so the automated GPS location associated with the response would be less likely to be the actual location where the respondent experienced the boom. The respondents did provide a “time of boom” that was different than the time that they posted the survey, so they did indicate that they were responding to a boom heard earlier in the day. They also provided locations. The risk reduction measures taken to have them provide the nearest street address, and whether they were within a few blocks of home or work allows the team alternate methods of geolocation. We are allowing the noise measurement to be estimated with square miles, as such it is realistic to have some leeway in the respondent location. A more detailed discussion on Geolocation is provide in 6.6.1 below.

For the single event survey 61 of the responses did not have an automated GPS location associated with them. The survey captured the location of 20 of those 61 responses as being at Lakeshore Drive from Respondent 47 (one of our team members). The SRC risk reduction map included an inquiry to confirm location and asked the respondent to provide their location if the GPS was incorrect. This add-on to the Qualtrics automated system worked to capture (in Data column “O”) the location as Lake Shore Drive, where apparently there was no GPS service. Of the remaining 41 responses, 40 responses that did not have automated GPS information responded that they were near work and outside or at work and inside, these location were available from the background survey (Data column “H”) with a typical location as Building

4800. One of the 61 respondents was at Branch Elementary School. For all 61 responses where the automated GPS did not work, the location was identifiable through the back up location methods.

The remaining 84 responses on the single event survey included eight that were delayed by more than one hour, however, all respondents entered a time in the entry for “time of the sonic boom”. Delays are to be expected in response as individuals go about their daily routine. These 84 responses included automated GPS locations for which those respondents noted that the geolocation was correct.

There is often signal interference on military installations and airports that could have affected the GPS availability, and our research team may not have known the street addresses of their field location. This was evident with closer examination of the data, which revealed that 13 of these 61 responses were associated with ID 45 (WSPRRR Engineer), for which the respondent indicated “Yes” the location was correct, however this team member recalls that at the time that the survey was completed, they could not discern if the location was correct based on the detail presented on the map. Upon further inspection of the data none of the automated geolocation points were in the vicinity of SBUDAS Alpha or SBUDAS Delta where the boom was experienced. Based on this experience, we can add a line to the instructions asking the respondent to provide the location at which they heard the boom if they have any uncertainty in the location provided in the automated GPS map. The team member with ID 48 indicated that the GPS was not correct for 5 of their responses, but could only provide a location for one of those responses, provided as 605 Bomb Circle. For ID 196 and ID 169, one automated GPS was on the lake bed. Respondent 196 appropriately indicated that their location was not correct, responded that they were at work and inside, and their work address was provided as Building 4800. Respondent 169 also indicated that their location was not correct, responded that they were at work and inside. They did not complete the background survey, but their work address was available from the recruitment survey as Building 4840. We’ll have to prompt all participants to complete the background survey, so that we have a complete set of information for all respondents. The backup location methods worked. A subset of the locations from which single event survey responses were submitted is presented in Figure 11.

Figure 11 Single Survey Event Response Locations. The majority of participants were clustered on site at AFRC. Responses noted to the north, south and west of AFRC were WSPRRR Engineers supplementing the participant pool.

6. Lessons Learned

6.1 SBUDAS Instrumentation

6.1.1 Multi-channel recordings

Upon the initial deployment of noise monitors on 8 May, it was found that one of the mics associated with Foxtrot was inoperable. Using the single operational channel, Foxtrot was successfully employed throughout the remainder of the event. The last flight day (Thursday 11 May) on the second flight significant differences between channels 1 and 2 were noted on Alpha. This might have been due to mic placement as it cleared up for the last flight, however having two channels significantly improved the capability to collect data.

6.1.2 Dedicated LMR Radio Operator

The base station operator should be accompanied by a dedicated LMR Radio Operator to minimize distractions and facilitate communications.

6.1.3 SBUDAS Calibration

For the AFRC Pre-Test we calibrated all monitors before and after each flight. The wide separation in SBUDAS caused this to be arduous though it was successfully accomplished throughout the week. This level of calibration was initially preferred to ensure fidelity of the recording and an accurate boom signature. A review of noise certification regulations regarding calibration requirements shows that the sensitivity to be used is an arithmetic mean of the pre/post "test series" calculated sensitivities with a 0.5dB (CFR Part 36) between subsequent calibrations. The sensitivity ratio (pre/post calibration ratio) that 0.5dB corresponds to can be can be calculated using the following expression:

$$20\log_{10}\left(\frac{sensitivity_1}{sensitivity_2}\right) = \Delta dB$$

For +0.5dB we get a ratio of 1.0593 and for -0.5dB we get a ratio of 0.9441; each of these reflect a 5.759% difference in sensitivities.

It is recommended that during the Final Community Response Test that calibrations only be conducted in the morning and at the close of each day.

6.1.4 Weather Proofing SBUDAS

On the afternoon of the first day of flights (Tuesday 9 May), it began raining, heavily at times. This prompted us to cancel the last flight and retrieve all noise monitors. The electronics enclosures are relatively secure against weather (though the SBUDAS do have a large opening for ventilation), however the microphones are the vulnerable to damage from moisture. We need to determine a method to either weatherproof the noise monitors or determine daily "Go-No Go" criteria based on the weather forecast for the day.

6.1.5 Cones and Reflectors

SBUDAS deployment kits should be stocked with cones and reflective tape for night time and early morning operations.

6.1.6 SBUDAS Power Requirements

The SBUDAS monitors were equipped with large single panel solar panels and large/heavy 12V Marine Batteries. These required large vehicles for transport and made deployment harder than it had to be. It is recommended that the SBUDAS power requirements be further assessed and smaller batteries and solar panels be utilized. We have collaborated with AFRC concerning the power system utilized by the SPIKE noise monitors.

6.1.7 Alternative SBUDAS positions

For the AFRC pre-test we received permission for the precise placement of SBUDAS monitors. In the future it is recommended that at least two locations for each SBUDAS monitor be defined in the event that it needs to be re-located either due to high ambient noise or modem connectivity.

6.1.8 Cellular Networking

Following the recording of the first boom the base station experienced excessive latency in connection and response with all SBUDAS. In the field R. Hunte was able to login through a cell phone browser and was able to verify that all modems were on line with good to excellent signal strength. This problem in connectivity caused us to cancel the second boom for the 0800 flight and ultimately to cancel the 1100 flight as we did not have SBUDAS connectivity necessary to satisfy "Go-No Go" criteria. The base station was then re-located in Larry Cliatt's office (removed from the vicinity of the command center) where cellular connectivity was restored, all SBUDAS were calibrated and "Go-No Go" criteria was satisfied by 1200 allowing the next flight to takeoff at 1330 local time. The reason for the initial loss of connectivity cannot be conclusively identified, though contributing factors identified include:

- A Verizon network was installed in the building where the base station was located. This network consisted of a number of cellular network “repeaters” located throughout the building and relocating the base station allowed it to connect with a less burdened repeater.
- Network services for telnet, ssh, http and https were not disabled on all of the cellular modems associated with the base station and the SBUDAS noise monitors, a review of the cellular logs indicated a number of unknown IP addresses which were attempting to gain access to the modems. Non-vital network services for all cellular modems were disabled on Monday evening.

6.1.9 Cellular Modem VPN Configuration

The VPN configuration during the AFRC Pre-Test consisted of the base station modem with IPSec tunnels to all of the SBUDAS cell modems; each SBUDAS cell modem was configured with a single tunnel to the base station modem. For the Community Response Test all modems will be configured with IPSec tunnels to all other modems which will allow for swapping modems between components if necessary.

6.2 Base Station

6.2.1 Multiple Base Stations

During the event Matt Collmar (GSA) was the base station operator, as such he was responsible for the operation and coordinating the calibration of all six monitors. For the community response test there will be 12-13 SBUDAS. It is recommended that two base stations with individual operators be employed. This will prevent overloading of the base station operator and additionally provide redundancy in the event of a base station failure.

6.2.2 Base Station connection to the VPN via the internet.

The Base Station is the key node in the network. On the second flight of the first flight day (May 9) the base station was very slow to connect and receive responses from each of the SBUDAS. R. Hunte was notified and tested by logging into each of the noise monitors and the base station cellular modem from his cell phone at Alpha, signal strength and quality at all modems Exceptional to Acceptable. The Base Station was at its original location from which satisfactory testing had been accomplished. The Base station was then moved to Larry Cliatt’s office away from the control room where performance improved. We left it at this location for the remainder of the event where it performed well. Reliability of the base station’s connection to the VPN may be improved by allowing it to directly connect to the internet rather than through the cellular modem. APS will investigate running the base station with a network connection accessing the SBUDAS VPN via OpenVPN. In the future the noise monitors and base station should be installed and field tested for validation in sufficient time prior to any flights.

6.2.3 The base station does not need to be in the command center

We initially thought that the base station was needed in the command center to provide feedback to the PI as to what the boom metrics were for each monitor. Since the Command Center utilizes CISBoomDA for real time boom feedback, colocation of the base station is not required providing more flexibility in system deployment.

6.3 Window Length for Calculation of Metrics

For WSPR 2011 the window length for calculation of metrics was limited to 650ms (encompassing only the initial boom). Given that participants will be unacquainted with sonic booms it is likely that their response will be to the full event. The 650ms window as used during WSPR 2011 will continue to be utilized.

6.4 Communications

6.4.1 Minimization

Communications should be minimized, unless a specific station is called acknowledgement should not be required.

6.4.2 Circuits

Two circuits were utilized: 1 the PI circuit and 2 NASA Ground. NASA Ground was the bridge between these two circuits. SBUDAS data collection was the priority and the team leader was occasionally fielding queries from the PI through NASA Ground to dynamic conditions concerning SBUDAS operations. This relay induced delay and in some cases confusion. There needs to be a more direct link between all key responsible roles.

6.4.3 Text

Throughout the event we kept a running text message between all SBUDAS personnel and key roles. This should be for information purposes only (as a log) all decisions need to originate via radio transmission on the PI circuit. Additional information sent to those on the text message group included anticipated boom propagation times to the control room. It was also used to convey footprint graphical information which facilitated diagnosing of Charlie being outside of the footprint hence not recording booms. A sample of the text messaging stream is presented in Figure 12.

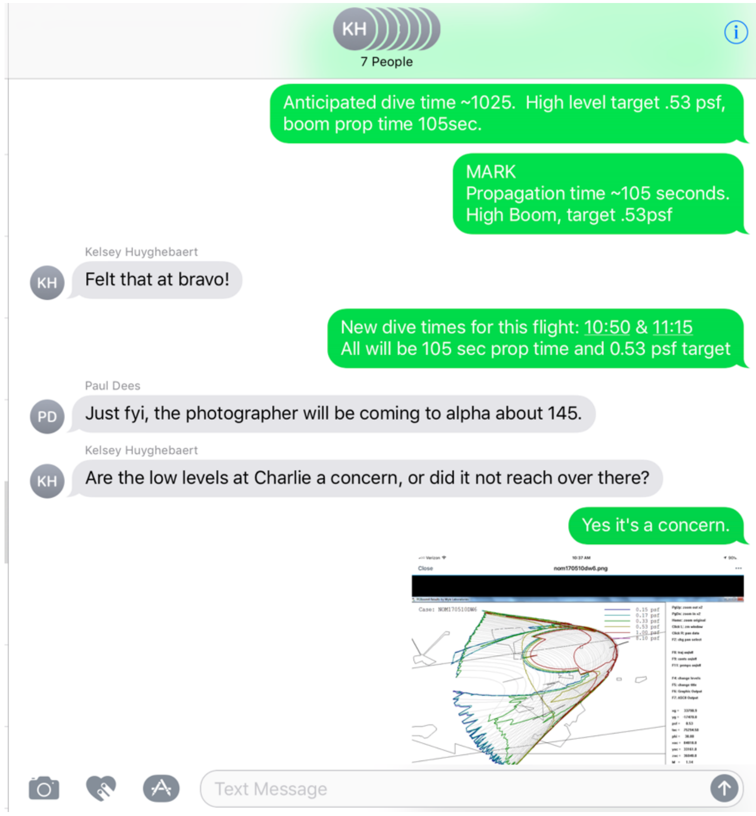


Figure 12 Example Text Segment

6.4.4 LMR Radios

NASA provided LMR radios for use during the Pre-Test event. These radios were extremely useful in coordinating activities in the field (far better than could be accomplished via cell phone or text) and provided closed circuits. For the final Community Response Test the NASA LMR Radio tech advised that he would require six months advance notice if we wanted to use them in the selected community.

6.5 Operations

6.5.1 Troubleshooting should only be conducted between flights

There were two instances when changes were attempted to either a noise monitor or with the base station while an aircraft was in the air. In one case some analysis was attempted on the base station while it was connected to the noise monitors (writing a file to excel). This caused the base station to lock up and induce an error state on all noise monitors. Resolution of this required rebooting the base station and then manually restarting each of the cRIOs in the SBUDAS. The boom for this flight was delayed but ultimately successfully completed on the flight. In the second case it was found that Charlie was outside the boom footprint. Recommendations were evolving concerning calculating new waypoints and redirecting the aircraft while in flight; rather than move the airplane/boom footprint the lead WSPRRR engineer (R. Hunte) initiated the relocation of SBUDAS Charlie, this was then decided against at which time Charlie was redeployed at its original location, calibrated and ready for operation in time for the scheduled boom. While we recovered in each instance the lesson learned is we need to be prepared for each flight and if something changes during the flight we should advise the PI as to the status for determination if the flight should continue.

6.5.2 Staffing

Having at least one person in the field that is free from having to remain at an assigned location (a floater) was beneficial. On the second day of flights the base station operator observed that Charlie was not being exposed to any booms. Having an operator on site at Charlie confirmed that no boom was audible. In another case on Thursday afternoon when differences were noted between channel one and two on Alpha it would have been helpful for this person to visit Alpha and ensure that a windscreen hadn't been removed or that the system had not been tampered with. This individual would additionally be available to run spare parts to SBUDAS engineers in the field to assist in trouble shooting and repair in between flights.

6.5.3 Analysis days

The AFRC Pre-Test spanned three days of busy data collection; between system deployment, calibration, and data collection little time was left to actually assess the data that was collected on each of the days. It would be useful during the final community response test to insert non-flight days to support assessment of the data being collected so that if changes are necessary they can be assessed and introduced into the next string of flight days.

6.5.4 Boom Observation notation

When keeping notes in the field it is recommended that a common simple lexicon be developed for characterizing audible booms. Following the test discussion concerning notes which noted “Double Boom” however as when queried as to what a “Double Boom” sounded like the engineer actually described “Boom Boom - Boom Boom”

6.5.5 Non –Escorted Access at AFRC

All WSPRRR personnel on the APS team required escorts within the AFRC complex. This restricted the movements of the APS Team and increased the manpower requirements of the AFRC team. In future events scheduled to be conducted at AFRC it is recommended that administrative action be taken to ensure unescorted access for visiting contractors in support of the event.

6.6 Subjective Data Collection

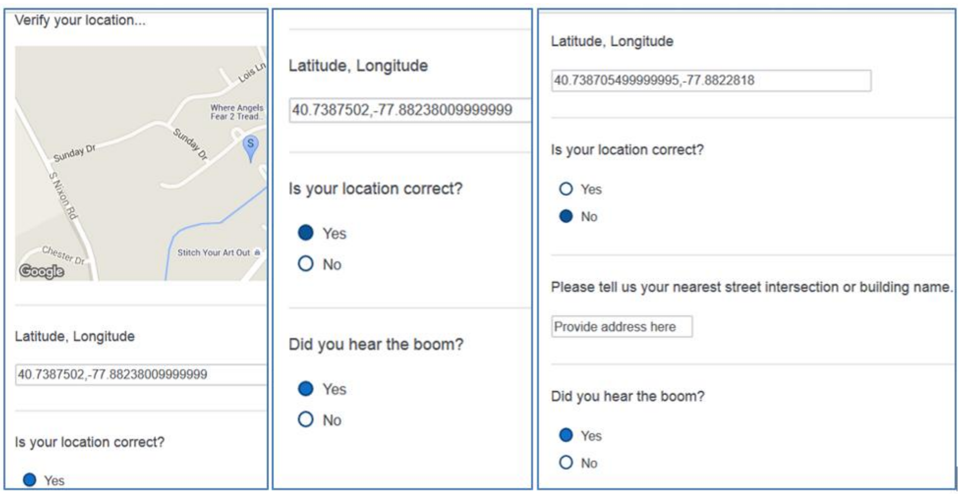
6.6.1 Subjective Response

We plan to prompt participants to complete all survey protocols. The background survey was not always completed for the AFRC dataset and it contains multiple questions that are potentially relevant for the statistical models. We also plan to change the content and time of delivery of the text prompts. Participants were randomly reminded several times per day that they should listen for booms. This subtle approach was proposed to avoid the appearance of attempting to influence the participants’ response. However, it does not allow us to discern if the respondents forgot to respond, or if they didn’t hear the boom. This may serve a purpose in justifying a more proactive approach of prompting a participant’s response. We plan to change the design and will send a text right after the boom asking “A boom may have occurred. Did you hear a boom? " so that we have less uncertainty in the response. We will also send this text a few times when there wasn't a boom, just to ensure that they are responding to the boom and not the text. This process will be included in the introductory consent information, so that they are aware that we will occasionally ask them if they heard a boom when no boom was presented. That allows the participant greater comfort in honestly replying either “yes” or “no” in response to the prompt.

This more proactive approach was initially not the method we were going to pursue as we were sensitive to accusations of introducing bias into our measurements. It is likely that the low response rate was because the low booms were not as loud as the booms that the recruits were accustomed to hearing on a daily basis. The low response rate might additionally have been due to too few high booms in the noise dose plan (necessary to get the participant’s attention). It was also recommended that the link to the survey be included in the text messages to facilitate compliance. This was accomplished in the later text messages. We can evaluate if this affected response rates when the statistical analysis is conducted.

6.6.1 Geolocation

Risk reduction measures were implemented to address the potential inaccuracy of the automated geolocation of a respondent and to verify their actual location. To determine if the location Qualtrics provides for a survey respondent is correct, The Penn State University Survey Research Center (SRC) developed a simple map based determination of location. This prototype utilizes a web app developed by Qualtrics™ which provides the latitude and longitude position of a participant responding through the Qualtrics survey app on a GPS-enabled device. A map is displayed and the respondent is prompted to reply if the location displayed is correct or not. If the location is not correct, the respondent can then manually enter their location. As further back up, the respondent provides both their home and work address as points of reference for potential responses.



If the respondent does not have a GPS-enabled device, the survey app will identify a location that is an approximation determined by comparing the participant's IP address to a location database. Inside the United States, this data is typically accurate to the city level. Where location is approximated, the longitude and latitude presented are of the geographic center of the most accurate location available for the respondent.

We are asking the respondent to verify their location and provide a correction of location as needed to ensure that we have the actual location. The backup location methods worked in the AFRC data set.

We do not need to automatically track the respondents using GPS. We trust them to provide their opinions and observations, and we should trust them to provide their location. There is the potential for negative public perception if it appears that we plan to track the participants to the meter, but are estimating the noise over miles. We should seek to have a range of tolerance for both the noise measurements and the participant locations that is balanced. Our team is executing due diligence in both the measurement of the noise and the location of the respondents, and some range estimation is acceptable, provided we can get the noise estimations to overlap with the respondent locations.

6.6.2 Recruitment

The recruitment utilized for the AFRC test employed different methods than those planned for the upcoming community field test. The following contains additional detail on the recruitment process for the community test that was recently identified. It is provided here for review and consideration as we finalize the site selection process.

The sample size for the community test is 500 respondents, so we are contacting 2000 households, with the assumption that we may only get recruits from 20 to 25 percent of the sample. This is realistic in survey research. There is sufficient address based sample at the proposed sites such that we should be able to attain a sufficient number of recruits. The PSU Survey Research Center is obtaining the potential sample using address based sample (ABS) from Survey Sampling International (SSI). The address based sample results in a universe of addresses from which a random sample may be generated. When defining a community, SSI does not use the community name because most states have multiple cities with the sample name. Typically, they use Zip Codes to define a survey community, but smaller geographies can be used. One concern would be how well these Zip Codes will fit the communities that are within the boom footprint. Zip Codes are used to make the delivery of mail easier, not defining city boundaries. To determine more specific boundaries underneath the boom footprint, census definitions (i.e., census tracts, block groups or blocks) may be used for greater geographic precision.

For an ABS sample, the smallest geography that can be used to define the communities' geography is a census block. Zip Codes or census blocks can be used to define a prospective community. Once the communities are defined and the universe of addresses determined, a random sample from the ABS database is generated. This can be done by the community or all the communities combined together.

Seasonal considerations should be made for both site selection and recruitment. The fall is still hurricane season and prospective geographies could be affected by weather events. It is often difficult to recruit participants between Thanksgiving and New Year's so the end of year holiday season should be avoided. There should be sufficient sample at all proposed location such that the address based sample in not a relevant factor for site selection. In the event that a site is selected that is prime for summer homes, the ABS can be used to identify those potential locations. There is a code in the ABS frame that denotes if a house is a seasonal home. The postal carrier makes that determination. However, this should only be used to better understand non-response rates, as there may be some coding errors for seasonal homes that are not coded, or homes that are coded as such and shouldn't be. A final variable is that the amount of the incentive ($5 incentive) may mean more in some of the communities than others.

6.6.3 Potential changes to Survey Protocols

Communications and Instructions

- Evaluate issues with initial emails from SRC going to receivers spam. Consider using PSU outgoing address to ensure delivery.
- Add a line to the instructions to clarify that they should manually enter their location if they are uncertain if the automated location provided in the GPS map is correct

Text prompts

- Provide text prompts to encourage completion of background survey
- Add daily text prompt to remind participants to complete Daily Survey at end of day
- Change text prompts delivery to just after each boom and several times randomly asking ""A boom may have occurred. Did you hear a boom? "
- Include link to the survey embedded within text messages

Survey Navigation Features to Investigate for Inclusion

- Evaluate potential option for respondents to go back within individual survey instrument when providing responses
- Implement dates in selectable format rather than as editable field
- Investigate options for creating short cut to Qualtrics survey for IPhone and androids

7. Appendices

A. Ground Operations Briefing May 8, 2017

Waveform and Sonic boom Perception and Response Risk Reduction (WSPRRR)

Ground Operations Briefing

May 8th 2017

Paul Dees

Commercial Supersonic Technology (CST)

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Agenda

- Schedule
- Ground Instrumentation
- Daily Duties and Assignments
- Equipment Locations and Directions
- Edwards AFB Guidelines
- Safety and Incident Response
- Wildlife Security
- Trash/Debris
- Communications Training

Introduction - Schedule

- WSPRRR Research Flights
  - 10 flights (16 flight opportunities)
  - Planned Tuesday to Friday between 5/9 and 5/12/2017
    - Tuesday – Thursday are primary (Friday as backup)
  - **Electrical outage at AFRC 5/5 – 5/7**

May 2017

Sun	Mon	Tue	Wed	Thu	Fri	Sat
	1	2	3	4	5 RDO	6
7 Contractor Arrival	8 Array Setup Briefings	9 3 Flights	10 4 Flights	11 3 Flights	12 Backup	13
14	15	16	17	18	19 RDO	20

Flight Schedule

Test Day	Takeoff Time (local)	# of Booms	Total # of Booms
1	0800	2	8
	1100	3	
	1400	3	
2	0800	3	10
	1000	2	
	1200	3	
	1500	2	
3	0800	2	6
	0930	2	
	1200	2	
		Total:	**24**

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Schedule

Test Day 1	
Time	Action
0500	Field crew arrives at AFRC, sets up arrays, perform preflight calibrations (as necessary)
0600	Waypoints calculated, emailed to flight crew
0600	Aircrew brief
0700	Control room staffing
0745	Ground Instrumentation Go/No Go status check
0800	F-18 takeoff & weather balloon launch
0900	F-18 land
1000	Control room staffing
1045	Ground Instrumentation Go/No Go status check
1100	F-18 takeoff & weather balloon launch
1200	F-18 land
1300	Control room staffing
1345	Ground Instrumentation Go/No Go status check
1400	F-18 takeoff & weather balloon launch
1500	F-18 land
1530	Aircrew debrief and prebrief
	Data downloads and review

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Schedule

Test Day 2	
Time	Action
0600	Field crew arrives at AFRC, sets up arrays, perform preflight calibrations (as necessary)
0700	Waypoints calculated, emailed to flight crew
0700	Control room staffing
0800	F-18 takeoff & weather balloon launch
0900	F-18 land
0900	Control room staffing
0945	Ground Instrumentation Go/No Go status check
1000	F-18 takeoff & weather balloon launch
1100	F-18 land
1100	Control room staffing
1145	Ground Instrumentation Go/No Go status check
1200	F-18 takeoff & weather balloon launch
1300	F-18 land
1300	Control room staffing
1445	Ground Instrumentation Go/No Go status check
1500	F-18 takeoff & weather balloon launch
1600	F-18 land
1630	Aircrew debrief and prebrief
	Data downloads and review

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Schedule

Test Day 3	
Time	Action
0600	Field crew arrives at AFRC, sets up arrays, perform preflight calibrations (as necessary)
0700	Waypoints calculated, emailed to flight crew
0700	Control room staffing
0800	F-18 takeoff & weather balloon launch
0900	F-18 land
0915	Ground Instrumentation Go/No Go status check
0930	F-18 takeoff & weather balloon launch
1030	F-18 land
1100	Control room staffing
1145	Ground Instrumentation Go/No Go status check
1200	F-18 takeoff & weather balloon launch
1300	F-18 land
1330	Aircrew debrief and prebrief
	Data downloads and review

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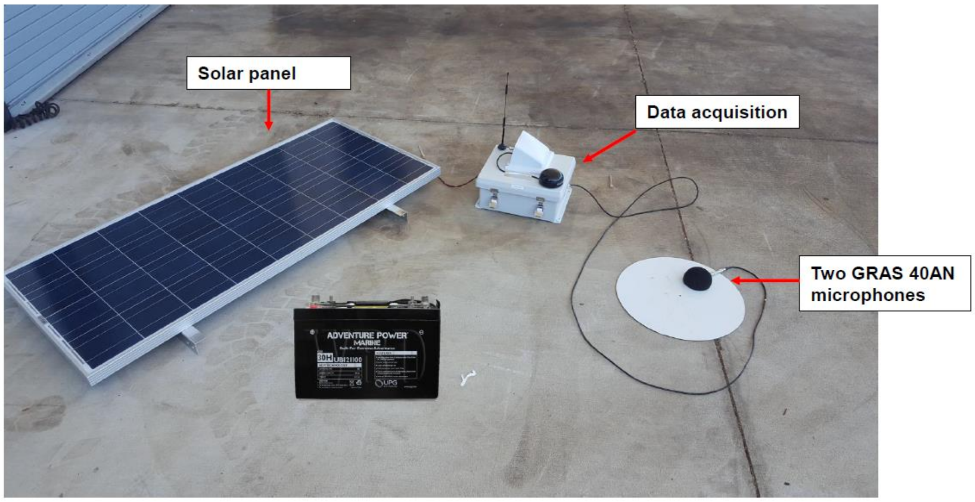
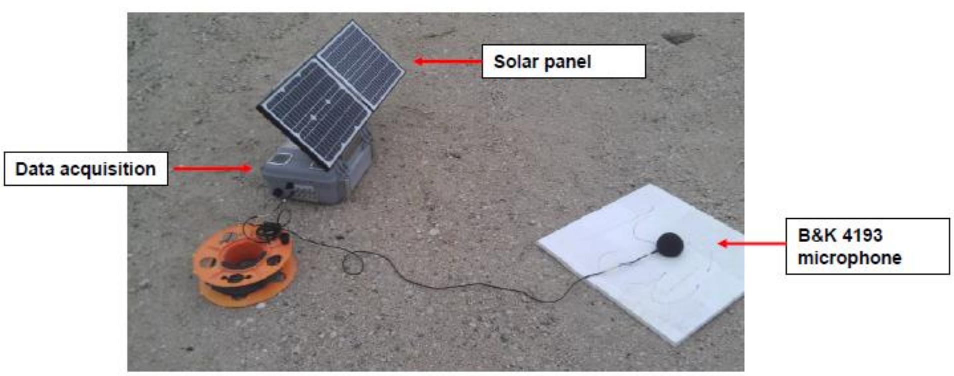
Ground Instrumentation – SBUDAS (aka GAcDAQ)

- Sonic Boom Unattended Data Acquisition Systems (SBUDAS) aka Gulfstream Acoustic Data Acquisition GAcDAQ)
  - Developed by Gulfstream
  - Remotely controlled (cellular)



Ground Instrumentation - SPIKE

- NASA Sonic Pressure Integrated Kit Electronics (SPIKE)
  - 8-channel National Instrumentation Compact RIO
  - 4-channel B&K Nexus microphone amplifier
  - Battery pack and solar charging system

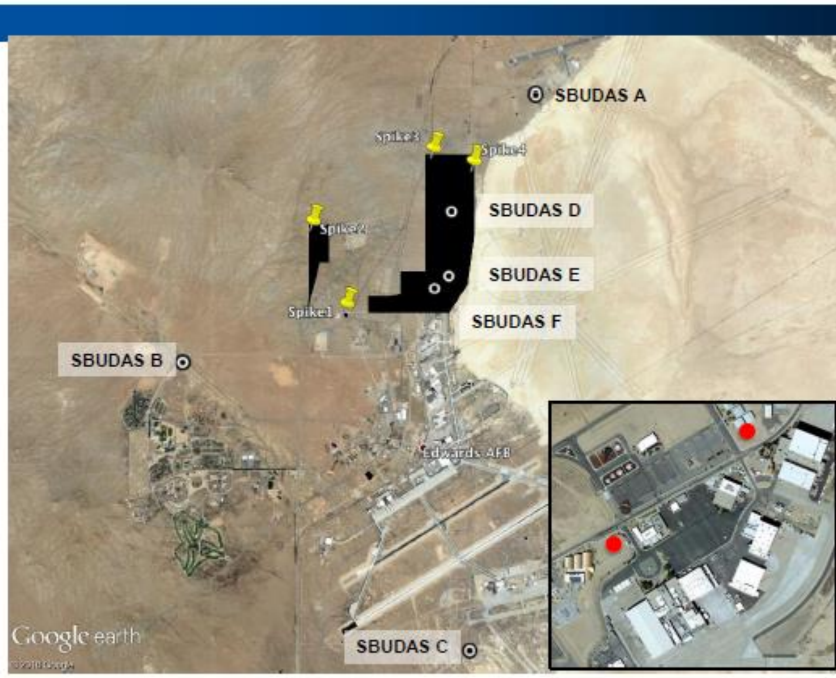


Atmospheric Instrumentation

- NASA Weather towers (3)
  - Each tower has anemometers, hygrometers, wind vanes, thermometers, and a barometer
  - Systems are solar-powered and operate autonomously for long-term data logging
  - Approximately 10-feet tall
  - To be deployed near SBUDAS-A, SBUDAS-C, and AFRC Area A
- GPSsonde weather balloons
  - Launched by EAFB (AFRC as backup)
- WeatherBug

NASA Weather Tower

Ground Instrumentation



AFRC Close-up

Test Day 1 Daily Duties and Assignments

Test Day 1	Array(s)									
Personnel	Spike 1	Spike 2	Spike 3	Spike 4	SBUDAS A	SBUDAS B	SBUDAS C	SBUDAS D	SBUDAS E	SBUDAS F
Paul Dees		x								
Erin Waggoner		x								
Ed Haering				x						
Sam Kantor	x									
Mike Hill			?							
Bob Hunte					x			x		
Kelsey Huyghebaert						x	x			
Juliet Page										
Matt Collmar									x	x

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Test Day 3 Daily Duties and Assignments

Test Day 3	Array(s)									
Personnel	Spike 1	Spike 2	Spike 3	Spike 4	SBUDAS A	SBUDAS B	SBUDAS C	SBUDAS D	SBUDAS E	SBUDAS F
Paul Dees	Float									
Erin Waggoner		x								
Ed Haering				x						
Sam Kantor	x									
Mike Hill			?							
Bob Hunte					x			x		
Kelsey Huyghebaert						x	x			
Juliet Page										
Matt Collmar									x	x

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Ground Instrumentation SPIKE 1

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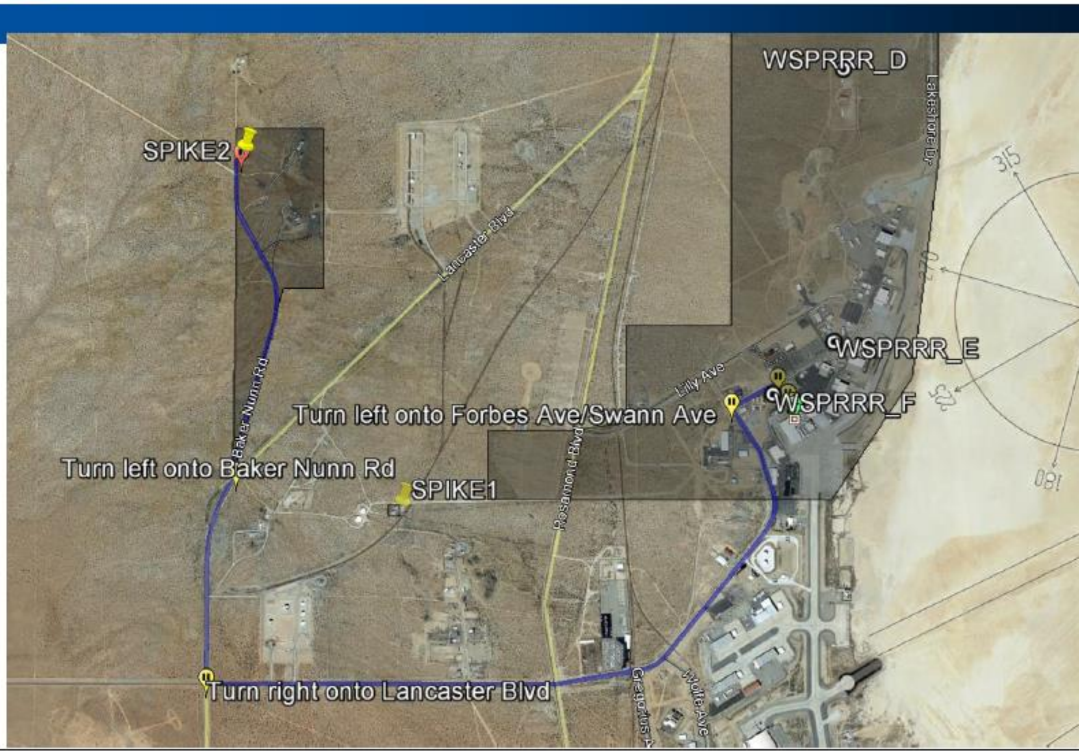
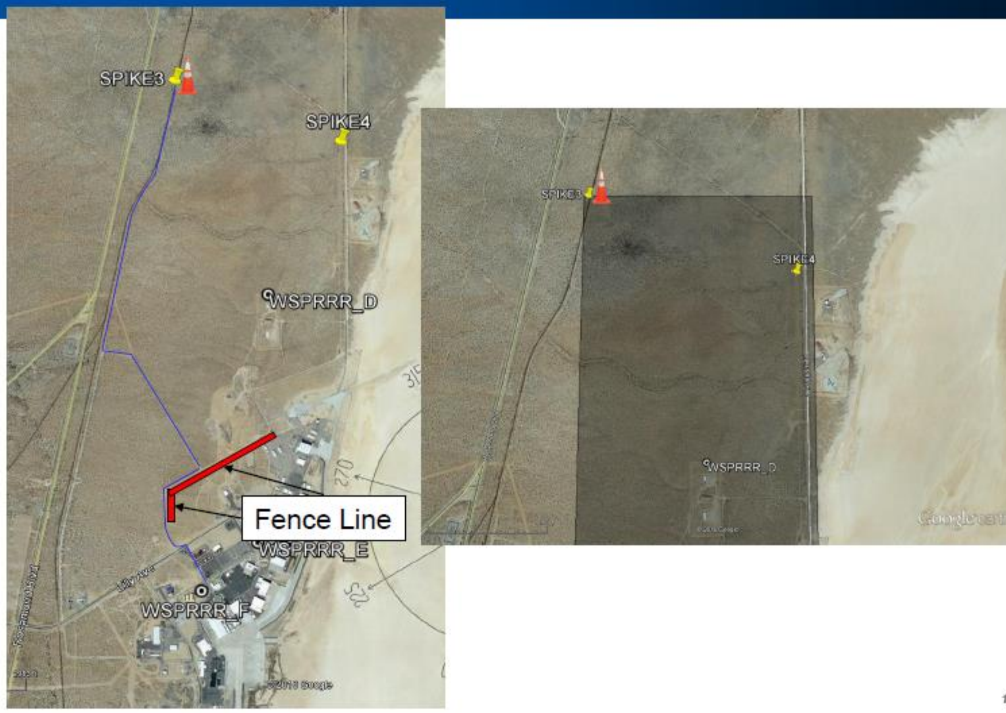
Ground Instrumentation SPIKE 2



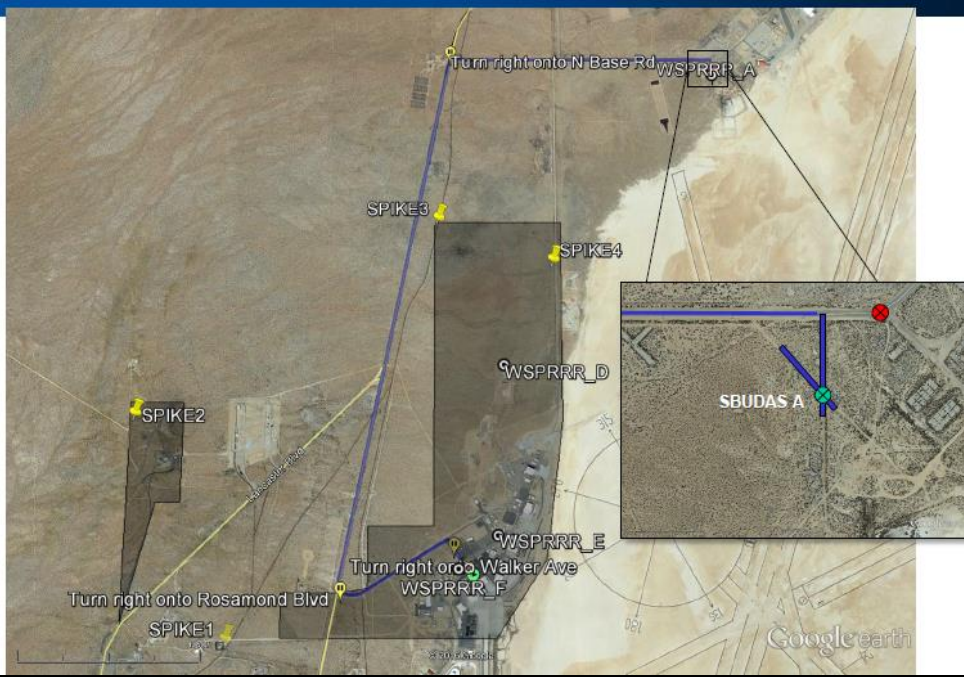
6

Ground Instrumentation SPIKE 3

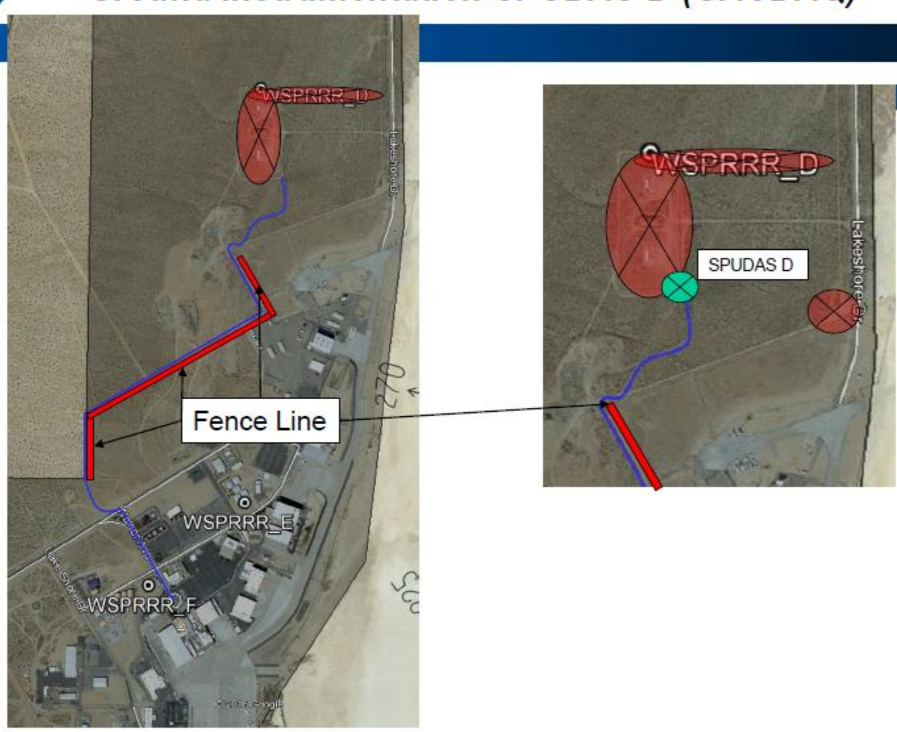


Ground Instrumentation SPIKE 4

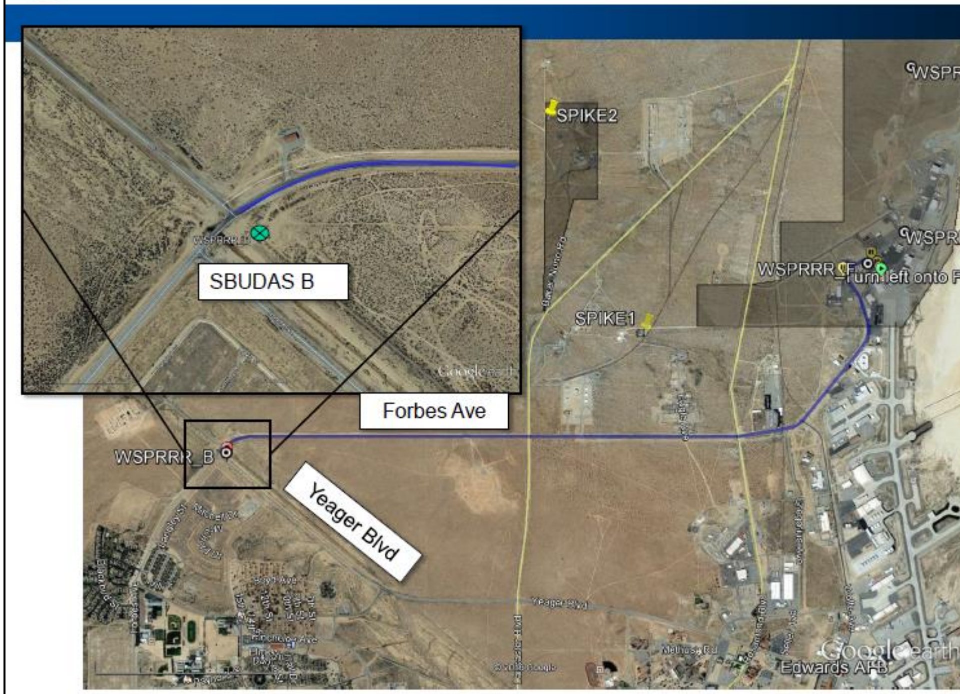
Ground Instrumentation SBUDAS A (GACDAQ)



Ground Instrumentation SPUDAS D (GACDAQ)



Ground Instrumentation SBUDAS B (GACDAQ)



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Ground Instrumentation SBUDAS C (GACDAQ) FROM B

22

Ground Instrumentation SBUDAS C (GACDAQ) FROM AFRC

23

Ground Instrumentation SBUDAS E & F (GACDAQ)

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Guidelines for working on Edwards AFB

- Desert Tortoise
  - Edwards AFB biologist survey requirement
  - Training for all field personnel in those areas
- Only use water-based spray paint to mark microphone locations
- No Driving Off Roads
- 20 mph limit on dirt roads
- Hand carry equipment off roads

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Safety and Incident Response

- Since traditional 911 services only work on landlines at Edwards AFB and most of SonicBAT's operations will take place in the field, incidents will most likely be reported by way of cellular phones using "AFRC 911."
  - **"AFRC 911" is phone number: 661-276-3256**
- Alternates:
  - **EAFB Security Services: 661.277.6901**
- All incidents must be reported to project PI
  - Personnel injury requiring immediate attention
    - Exception –Discomforts due to the field environment
      - Examples: Insect bite, sunburn, etc.
  - Damage to any equipment as a result of NASA actions (>$1000)
    - Exception – Environmental damage
      - Examples: Animal activities, dust contamination, wind damage, etc.

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Wildlife Security

- In the event of any wildlife issues or concerns contact:
  - EAFB Wildlife Sec Forces: 661.810.7896

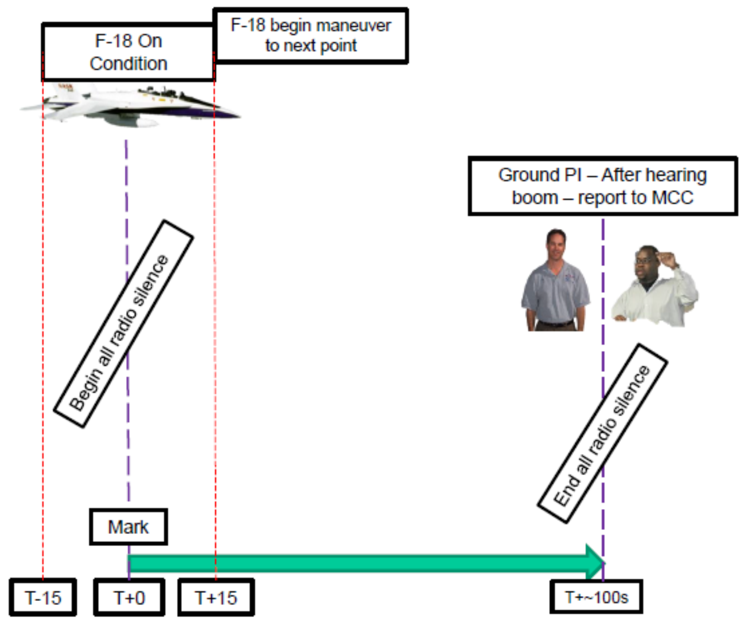
Trash/Debris

- Please be very aware of trash and other Foreign Object Debris (FOD) while out at the test site
  - Consider bringing your own trash bags to keep in vehicles while in desert
- The desert has the tendency to get windy. Please pay extra attention to the following
  - Debris/trash
  - Hats/headwear
  - Avoid having multiple doors open on vehicles (lest it become a wind tunnel)

Communications Training

- Each array site will have 1 radio
  - Not anticipated that there will be a lot of radio calls between arrays during flights, but it will help keep channels quiet and clear
  - No radio calls after the "Mark" until after boom is heard
- Call sign for each site is the name of the site
- When calling:
  - Who you are calling, who you are
    - Example: "Mission Control, Spike 1" to call Mission Control from Spike 1
  - Wait for response
  - Respond with your message

Communications Training Continued



Questions?


wsprrr
WAVEFORMS & SONICBOOM PERCEPTION AND RESPONSE
NASA
RISK REDUCTION

B. PCBoom Predictions and Waypoints

I. Monday May 8th Predictions for Tuesday May 9th

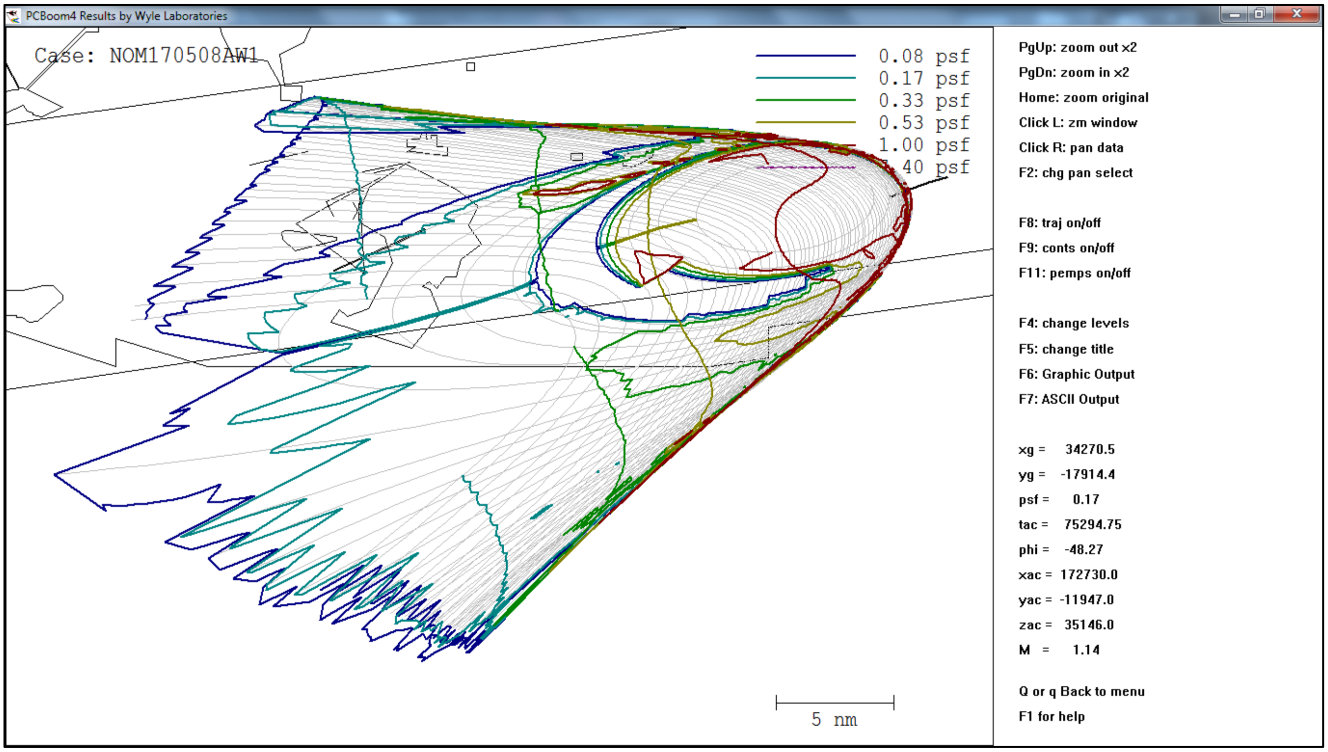


Figure 13 Predicted footprint for booms before 0830 based on m17050815z09forecast.atm weather file: nom170508aw1
F-18 Dive Point 34 56' 56"N, 117 29' 03"W 2541 Grnd 34:57:04 -117:53:14 161 0.17

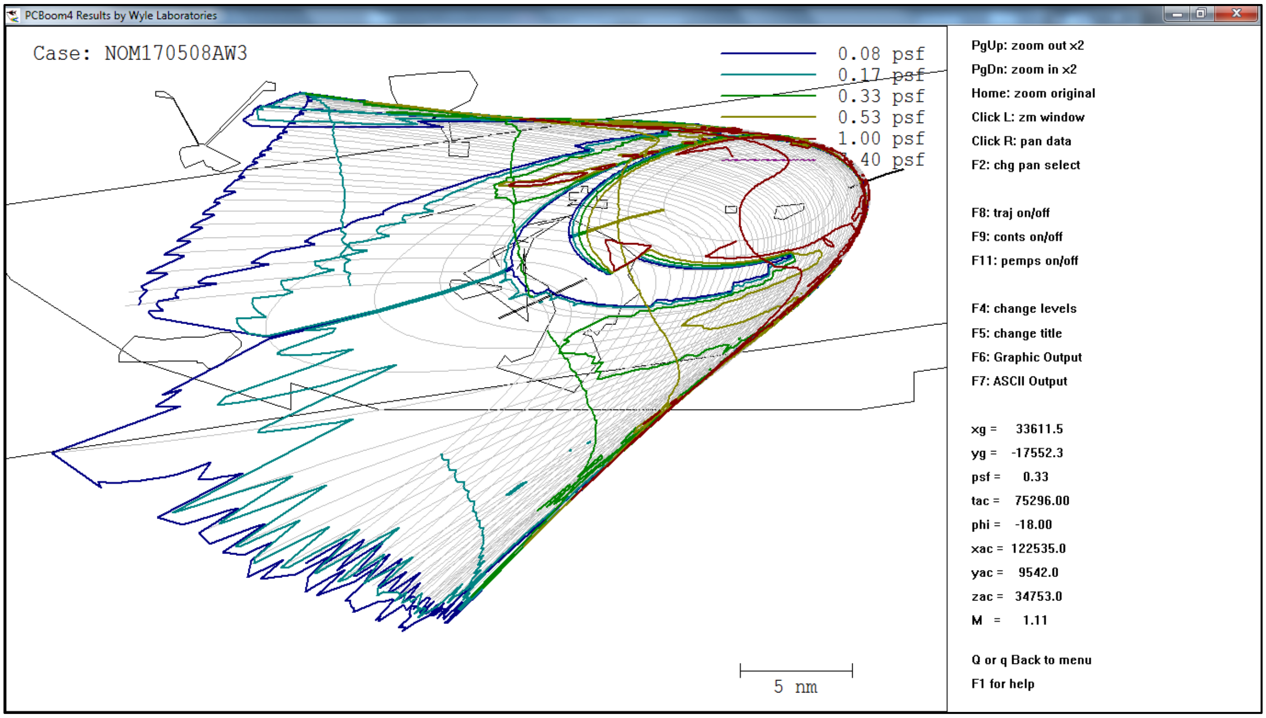


Figure 14 Predicted footprint for booms before 0830 based on m17050815z09forecast.atm weather file: nom170508aw3 F-18 Dive Point 35 00' 35"N, 117 38' 52"W 2462 Grnd 34:57:04 -117:53:14 121 0.33

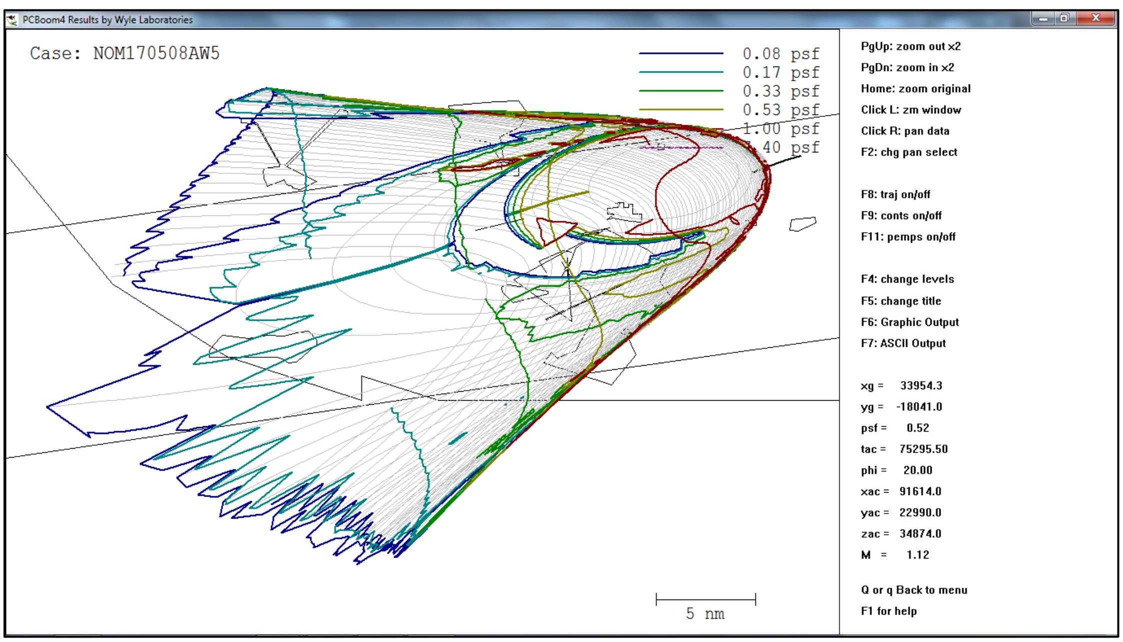


*Figure 15 Predicted footprint for booms before 0830 based on m17050815z09forecast.atm weather file: nom170508aw5 ***Likely to put focus boom on community west of Boron*** F-18 Dive Point 35 02' 44"N, 117 45' 11"W 2387 Grnd 34:57:04 -117:53:14 102 0.52*

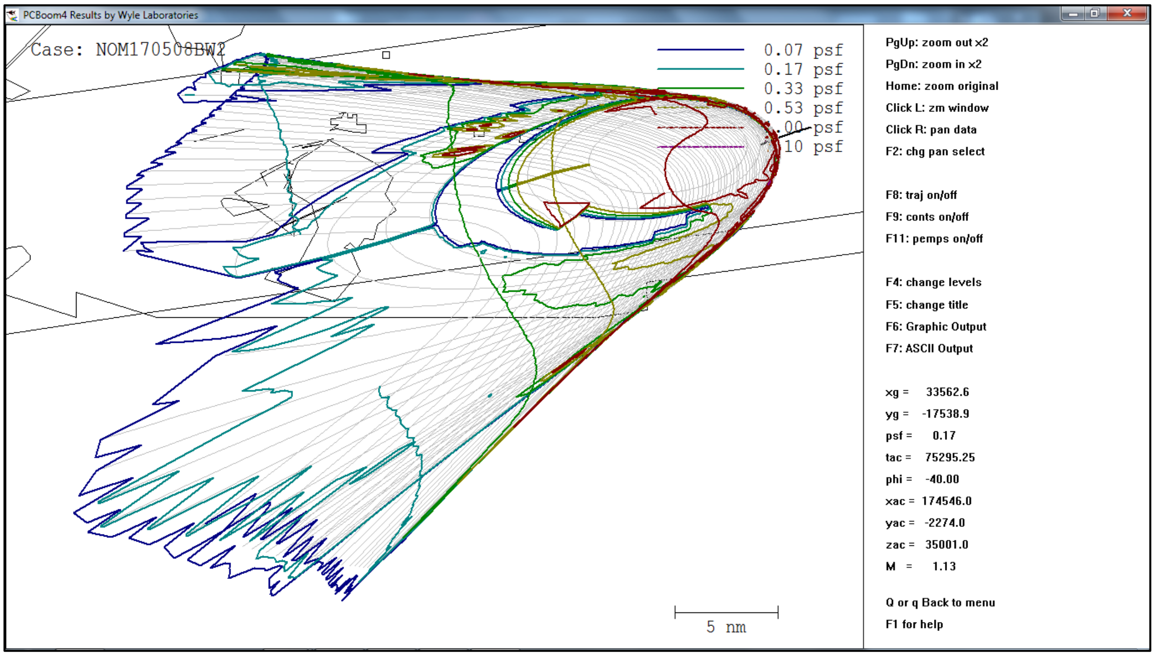


Figure 16 Predicted footprint for booms between 0830 and 0930 based on m17050816z10forecast.atm weather file: nom170508bw2 F-18 Dive Point 34 58' 33"N, 117 28' 36"W 2464 Grnd 34:57:04 -117:53:14 164 0.17

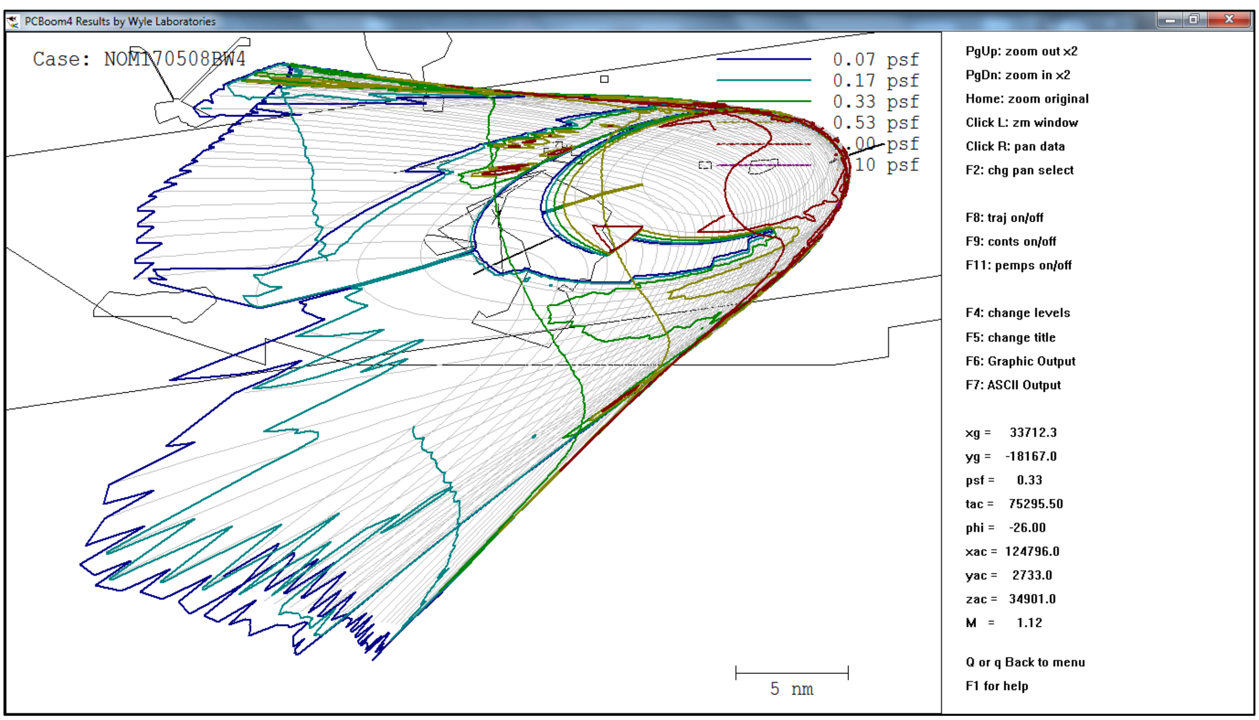


Figure 17 Predicted footprint for booms between 0830 and 0930 based on m17050816z10forecast.atm weather file: nom170508bw4 F-18 Dive Point 34 59' 24"N, 117 38' 32"W 2499 Grnd 34:57:04 -117:53:14 121 0.33

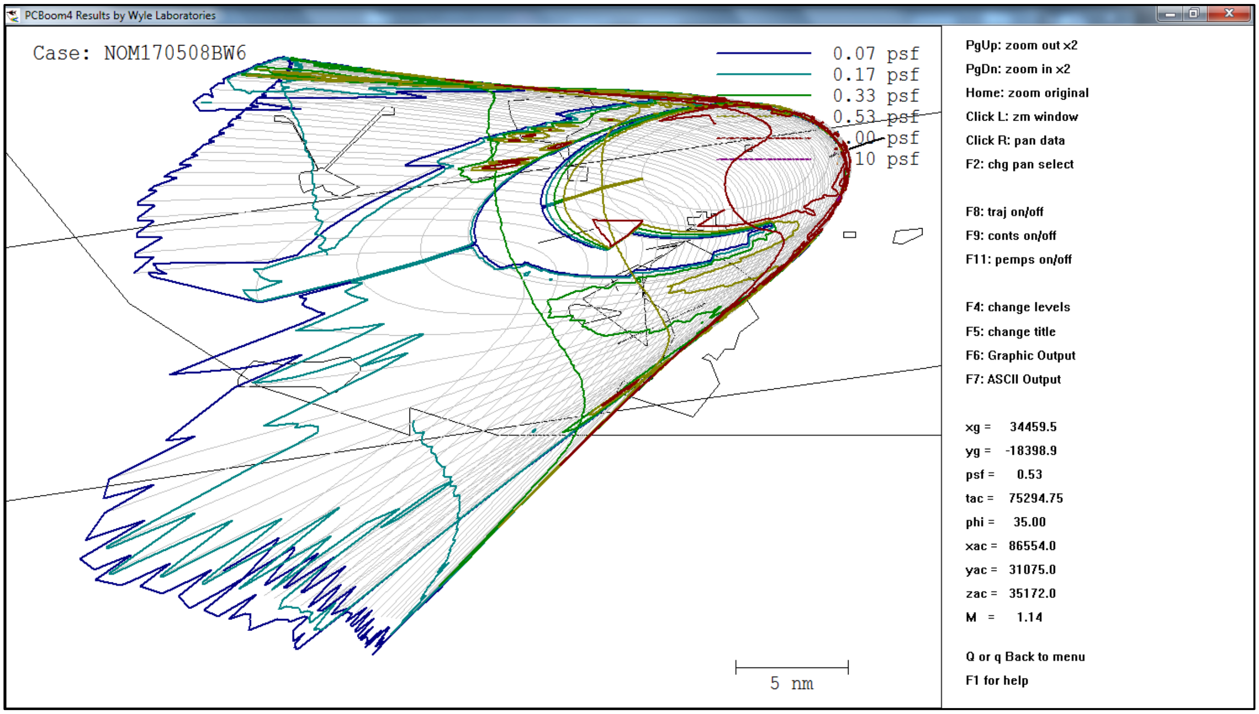


Figure 18 Predicted footprint for booms between 0830 and 0930 based on m17050816z10forecast.atm weather file: nom170508bw6 F-18 Dive Point 35 03' 60"N, 117 46' 23"W 2391 Grnd 34:57:04 -117:53:14 102 0.53

II. Tuesday May 9th

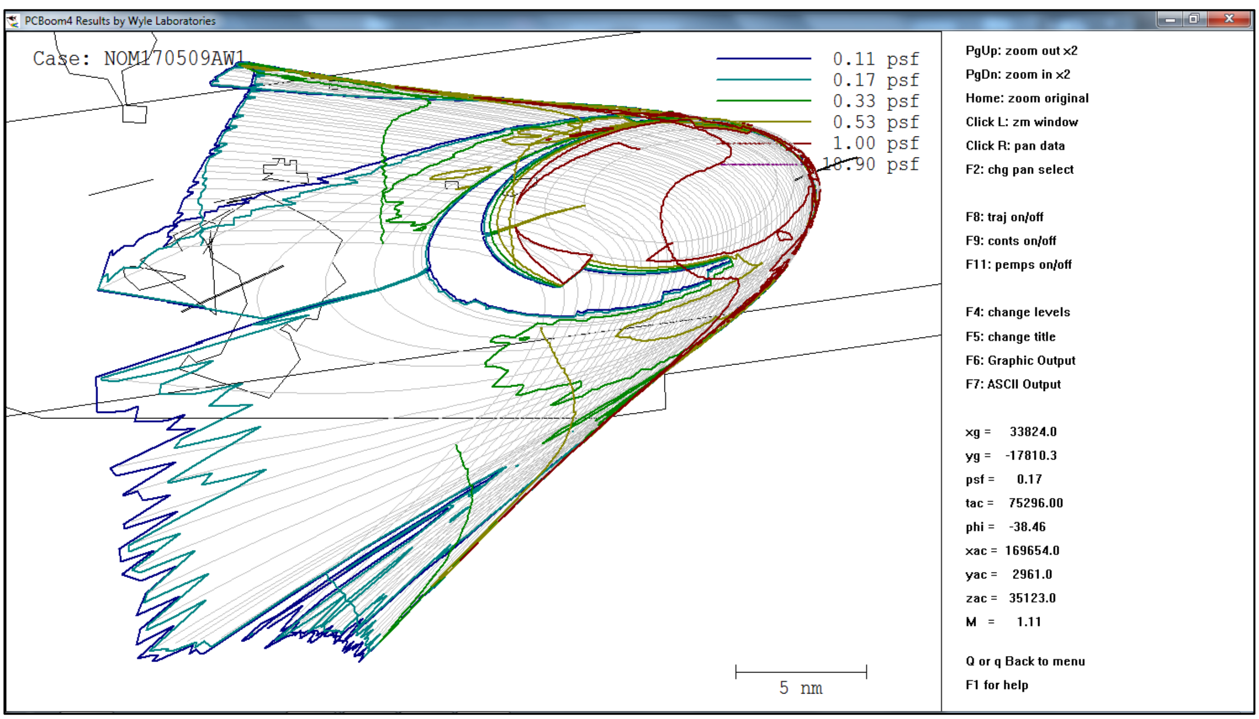


Figure 19 ***For booms before 8:30AM local time:*** *m17050915z09forecast.atm weather file nom170509aw1 F-18 Dive Point 34 59' 25"N, 117 29' 25"W 2412 Grnd 34:57:04 -117:53:14 162 0.17*

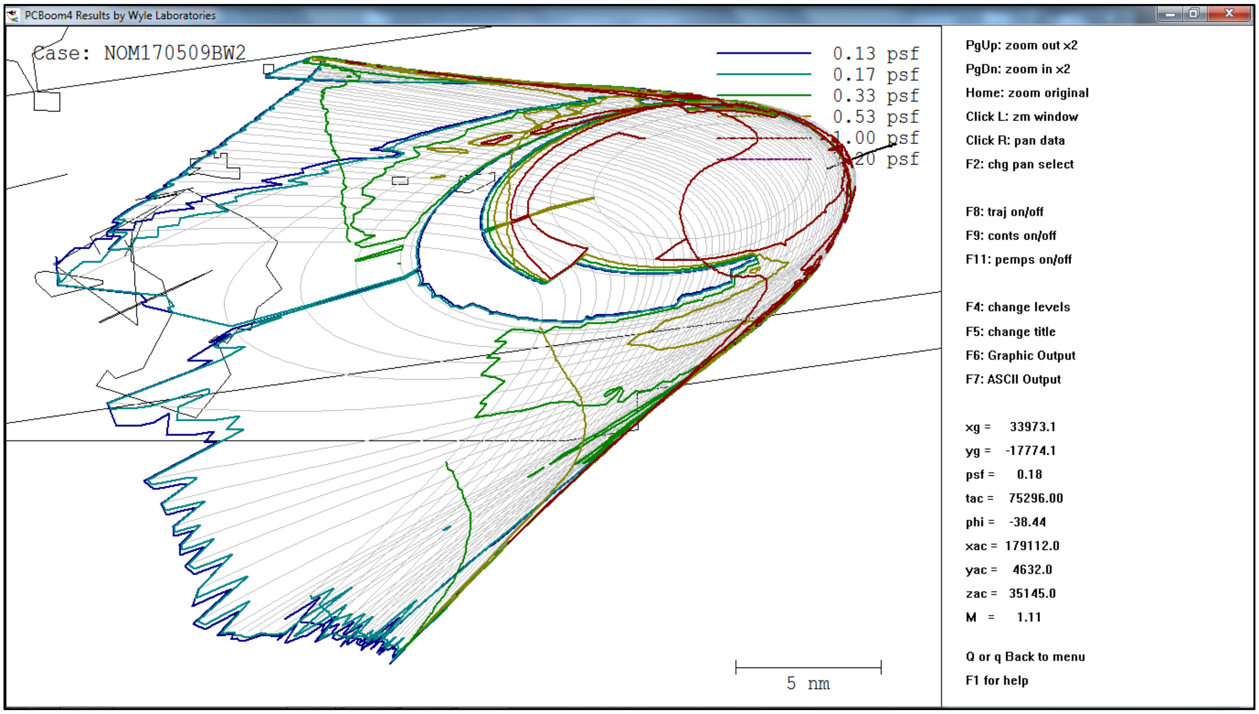


Figure 20 ***For booms after 8:30AM up to 9:30AM local time:*** *m17050916z10forecast.atm weather file nom170509bw2 F-18 Dive Point 34 59' 41"N, 117 27' 33"W 2377 Grnd 34:57:04 -117:53:14 170 0.18*

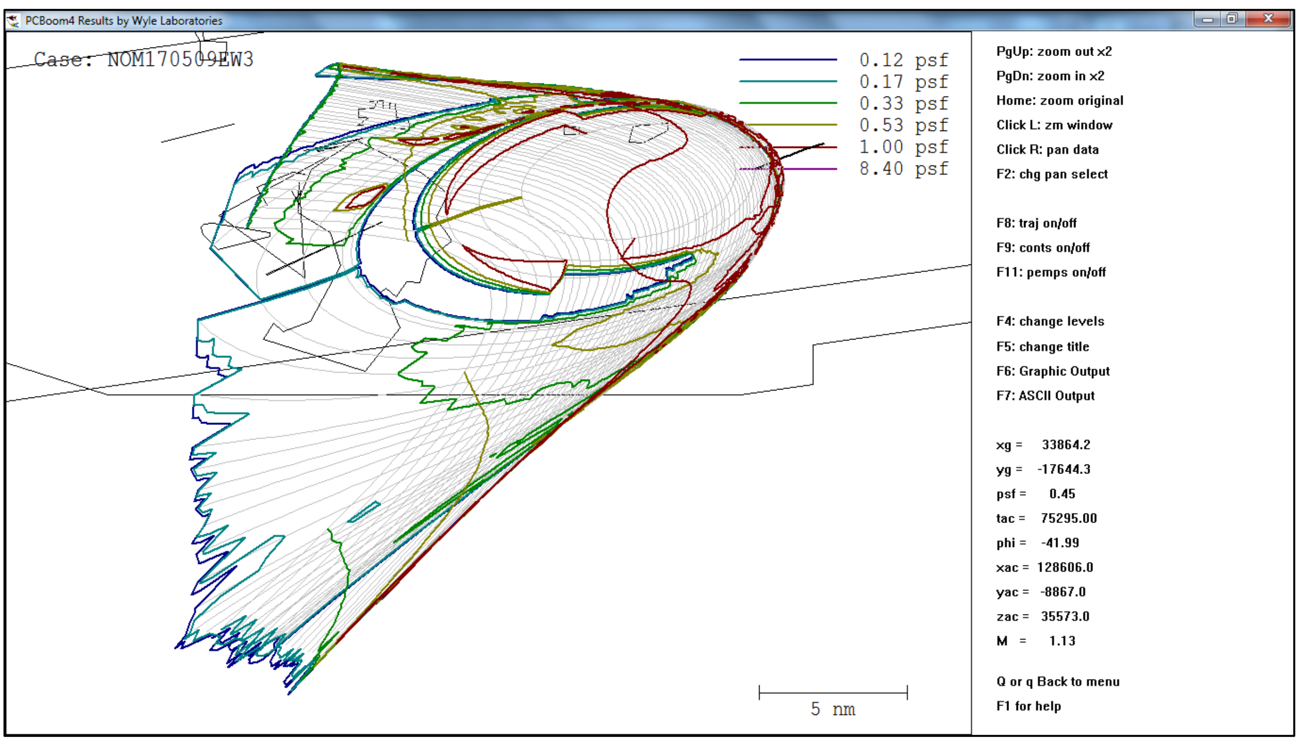


Figure 21 The predicted boom footprint before 1430 local time on 5/9/17: nom170509ew3 F-18 Dive Point 34 57' 21"N, 117 37' 48"W 2735 Grnd 34:57:04 -117:53:14 125 0.45

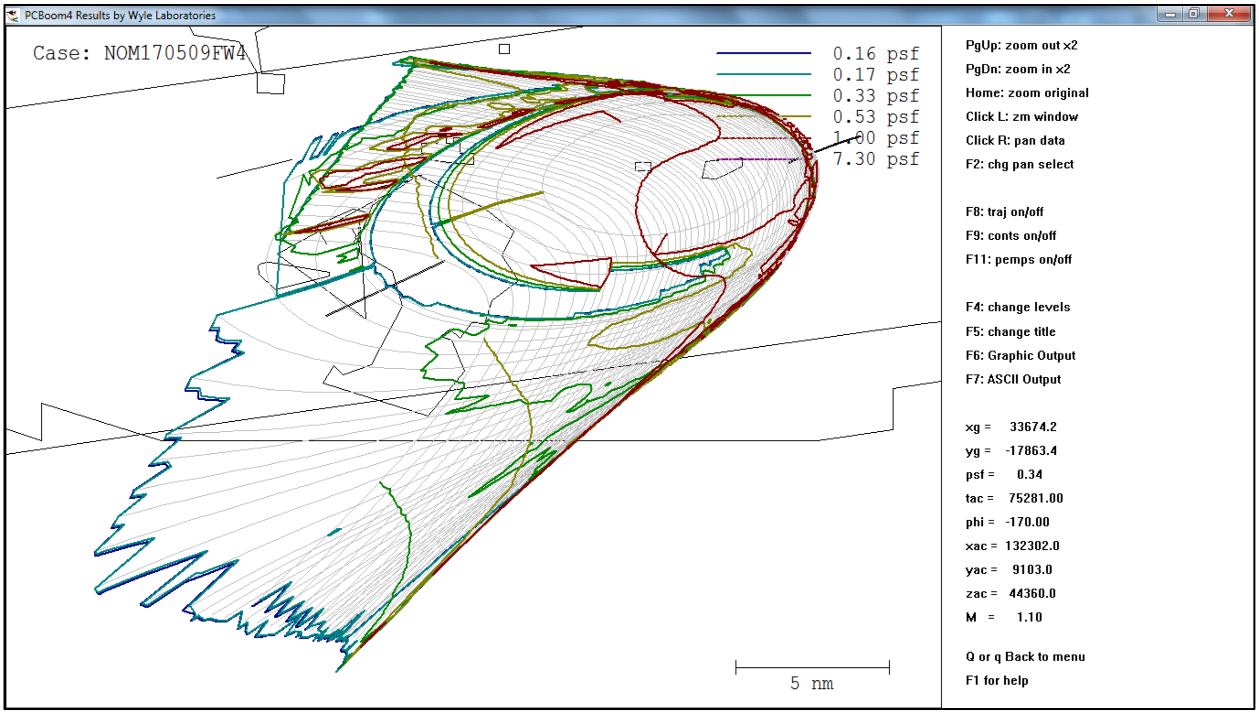


Figure 22 The predicted boom footprint after 1430 local time on 5/9/17: m17050922z10forecast.atm weather file nom170509fw4 F-18 Dive Point 34 59' 15"N, 117 39' 38"W 2488 Grnd 34:57:04 -117:53:14 120 0.34

III. Wednesday May 10th

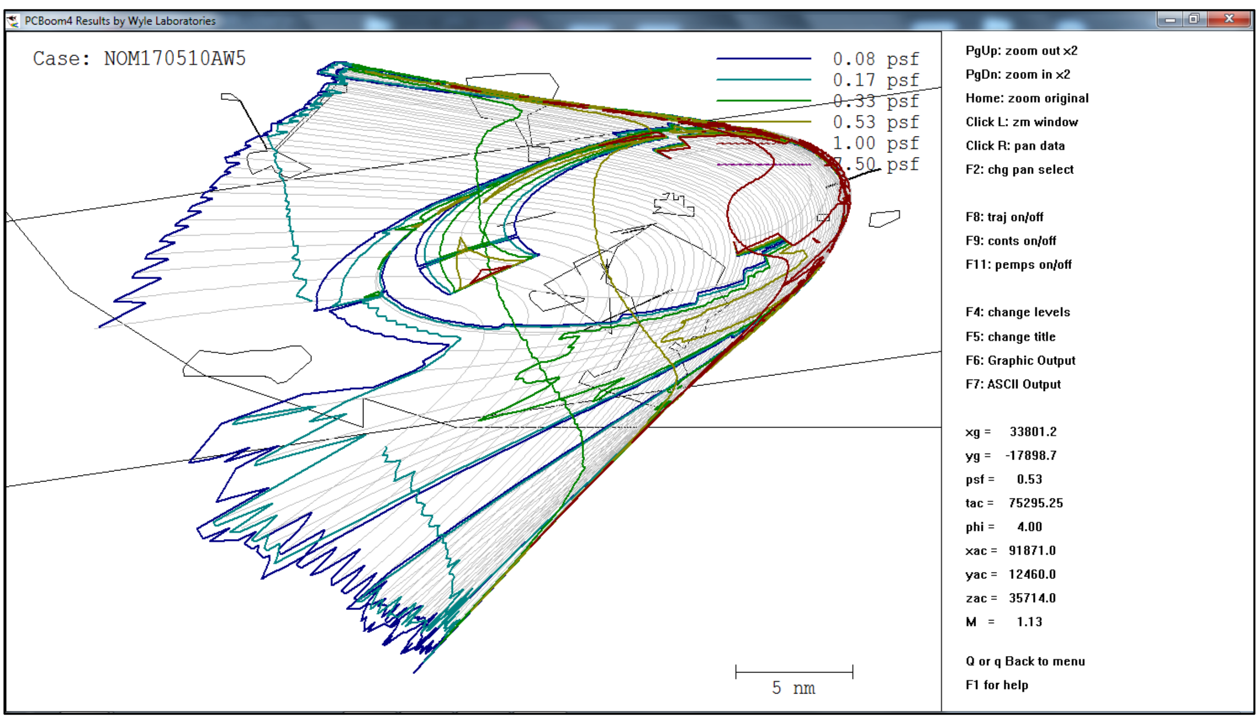


Figure 23 ***For booms before 08:30AM local time:*** *m17051015z09forecast.atm weather file nom170510aw5 F-18 Dive Point 35 00' 55"N, 117 45' 13"W 2356 Grnd 34:57:04 -117:53:14 100 0.53*

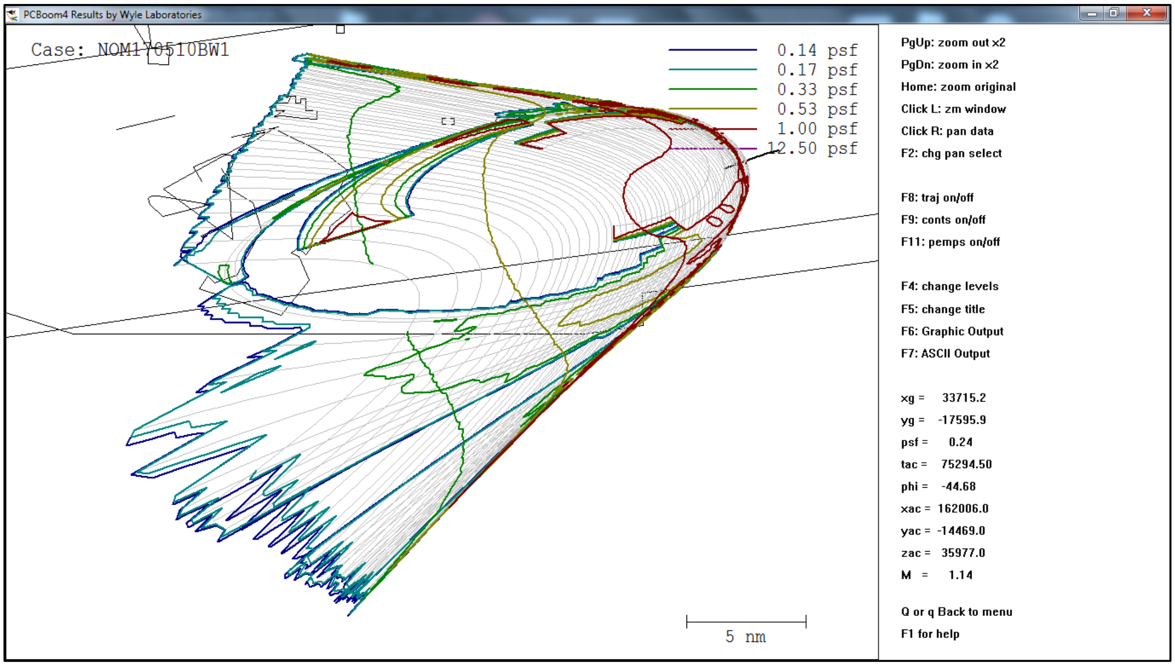


Figure 24 ***For booms between 08:30AM and 9:30AM local time:*** *m17051016z10forecast.atm weather file nom170510bw1 F-18 Dive Point 34 56' 27"N, 117 31' 16"W 2686 Grnd 34:57:04 -117:53:14 155 0.24 (furthest downrange of the carpet, can't get much lower)*

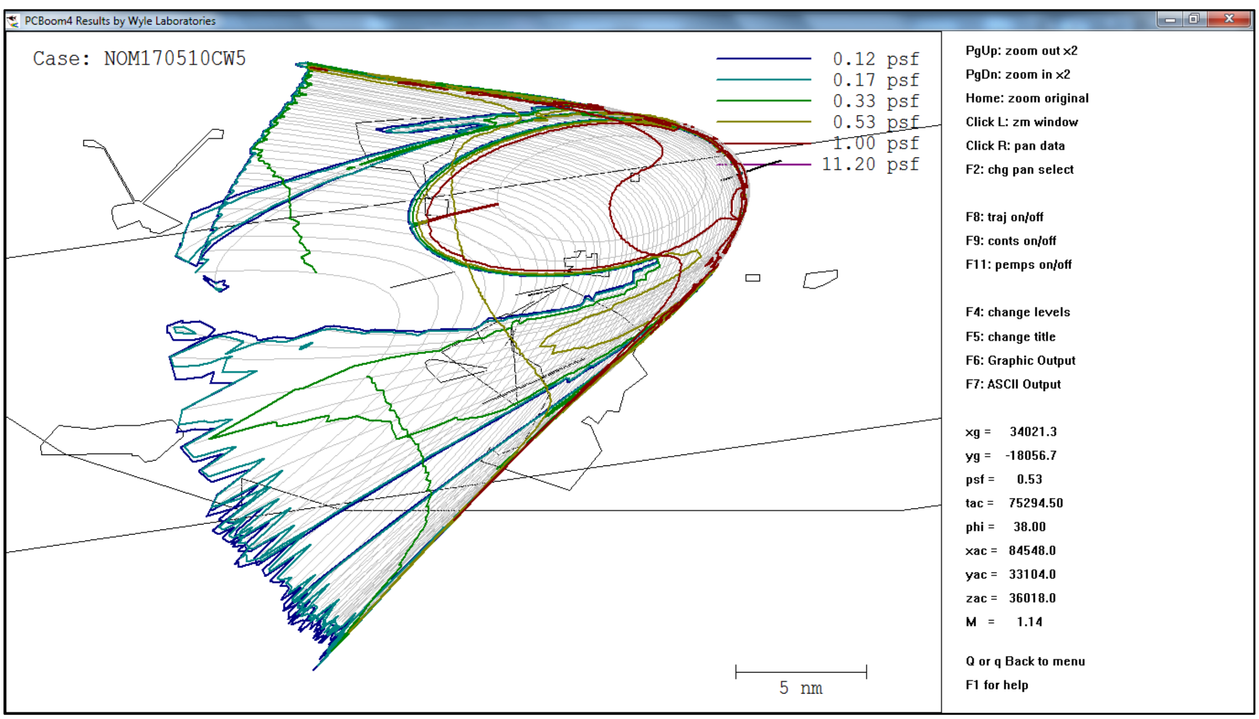


Figure 25 ***For booms before 10:30AM local time:*** *m17051017z05forecast.atm weather file nom170510cw5 (north edge of HSSC) F-18 Dive Point 35 04' 12"N, 117 46' 47"W 2384 Grnd 34:57:04 -117:53:14 104 0.53*

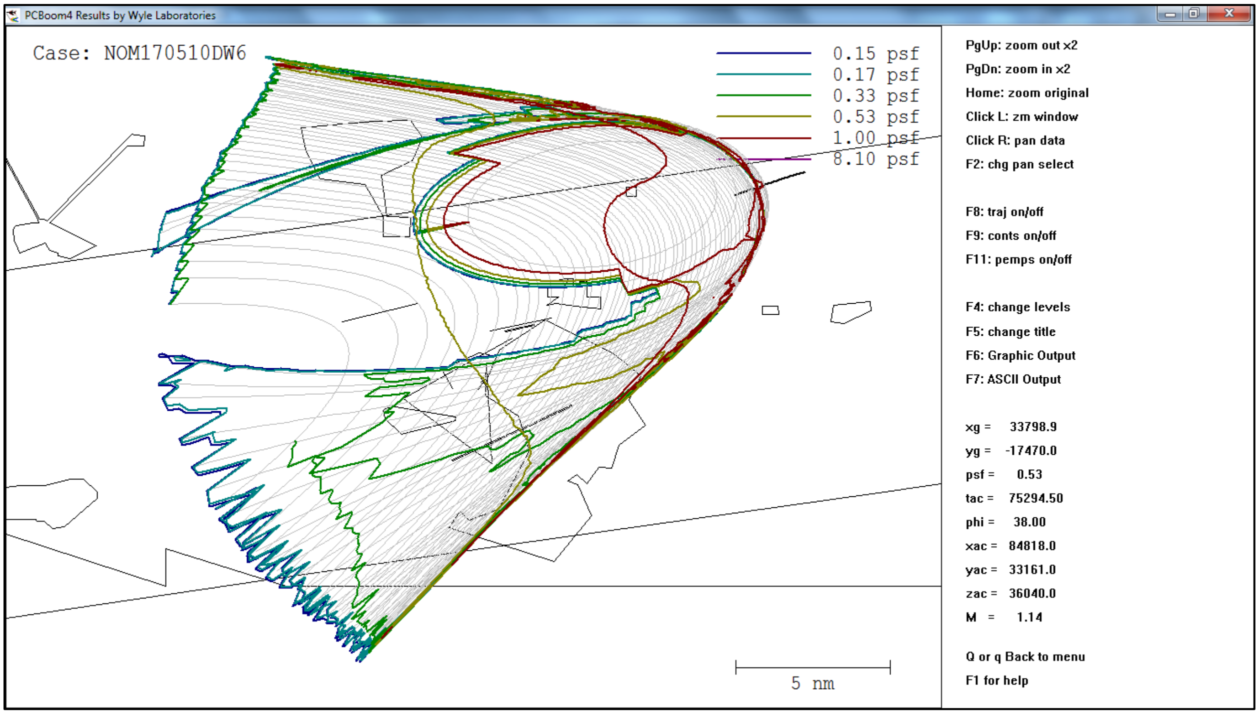


*Figure 26 **For booms between 10:30AM and 11:30AM local time:** m17051018z06forecast.atm weather file nom170510dw6 (looks like this is within 300' of the above point, so you can use the same for both) F-18 Dive Point 35 04' 12"N, 117 46' 44"W 2388 Grnd 34:57:04 -117:53:14 105 0.53*

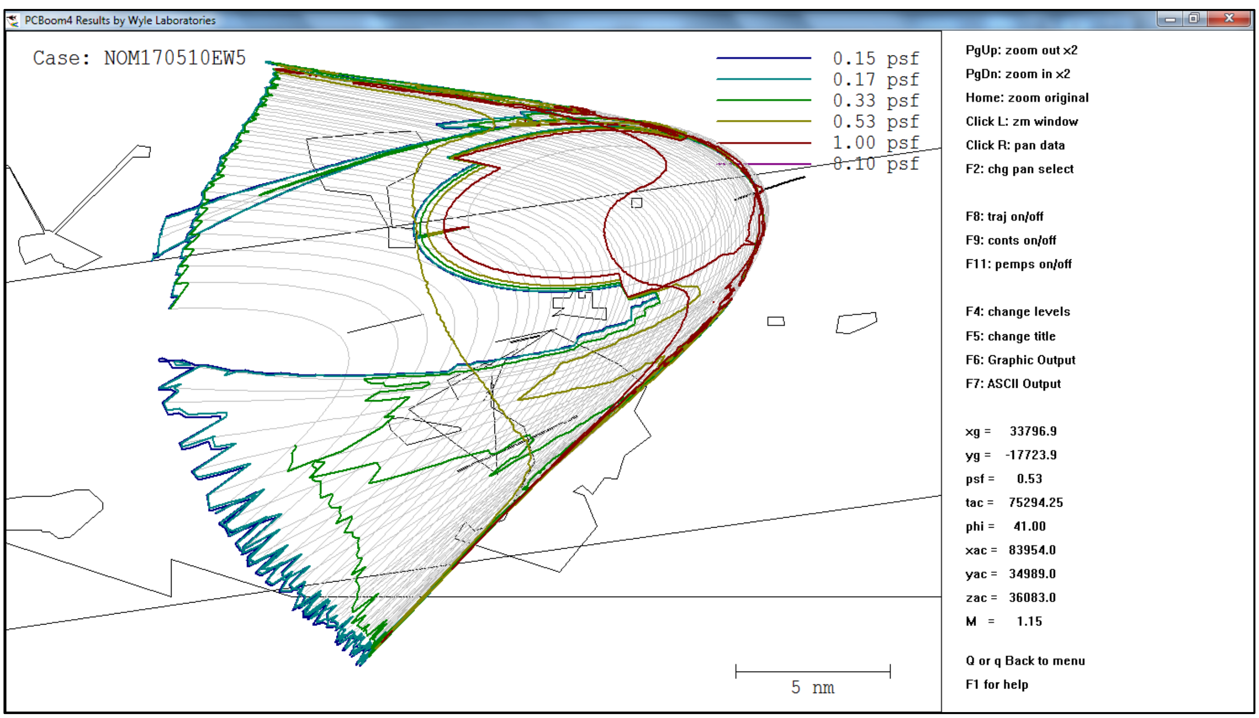


*Figure 27 **For booms before 12:30PM local time:** m17051018z06forecast.atm weather file nom170510ew5 F-18 Dive Point 35 04' 29"N, 117 46' 57"W 2391 Grnd 34:57:04 -117:53:14 105 0.53*

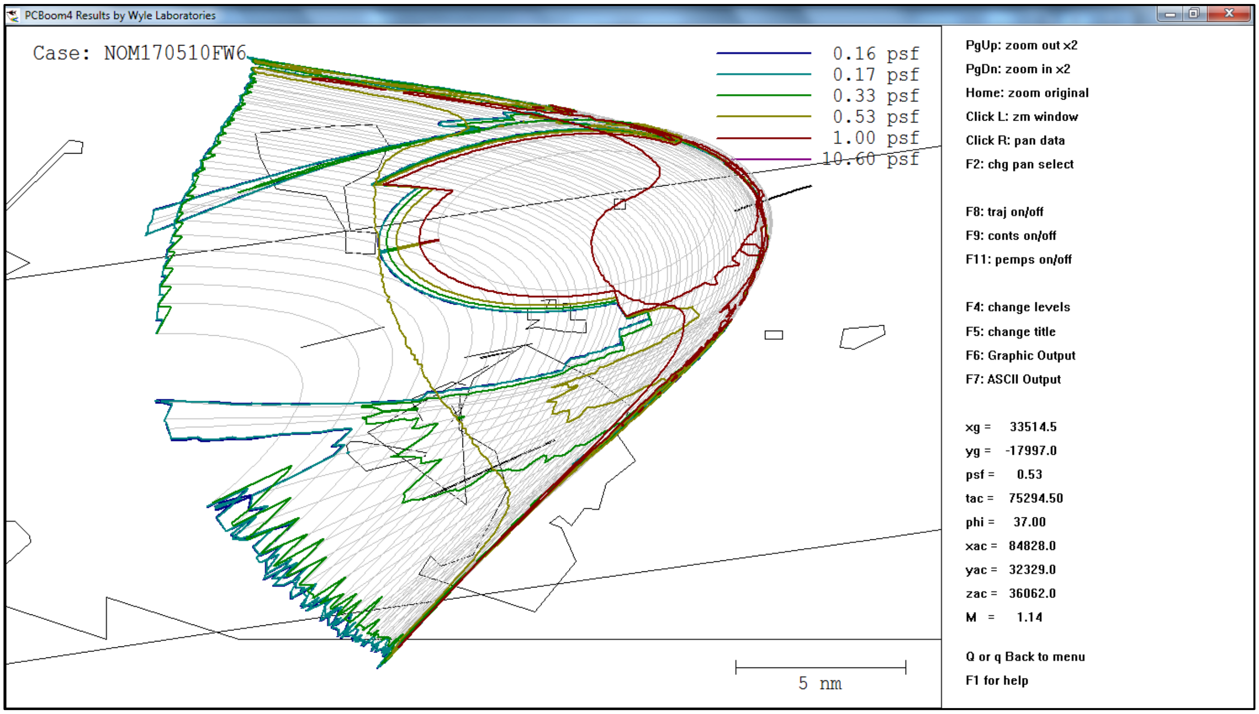


Figure 28 ***For booms between 12:30PM and 1:30PM local time:*** *m17051019z07forecast.atm weather file nom170510fw6 F-18 Dive Point 35 04' 04"N, 117 46' 42"W 2380 Grnd 34:57:04 -117:53:14 105 0.53*

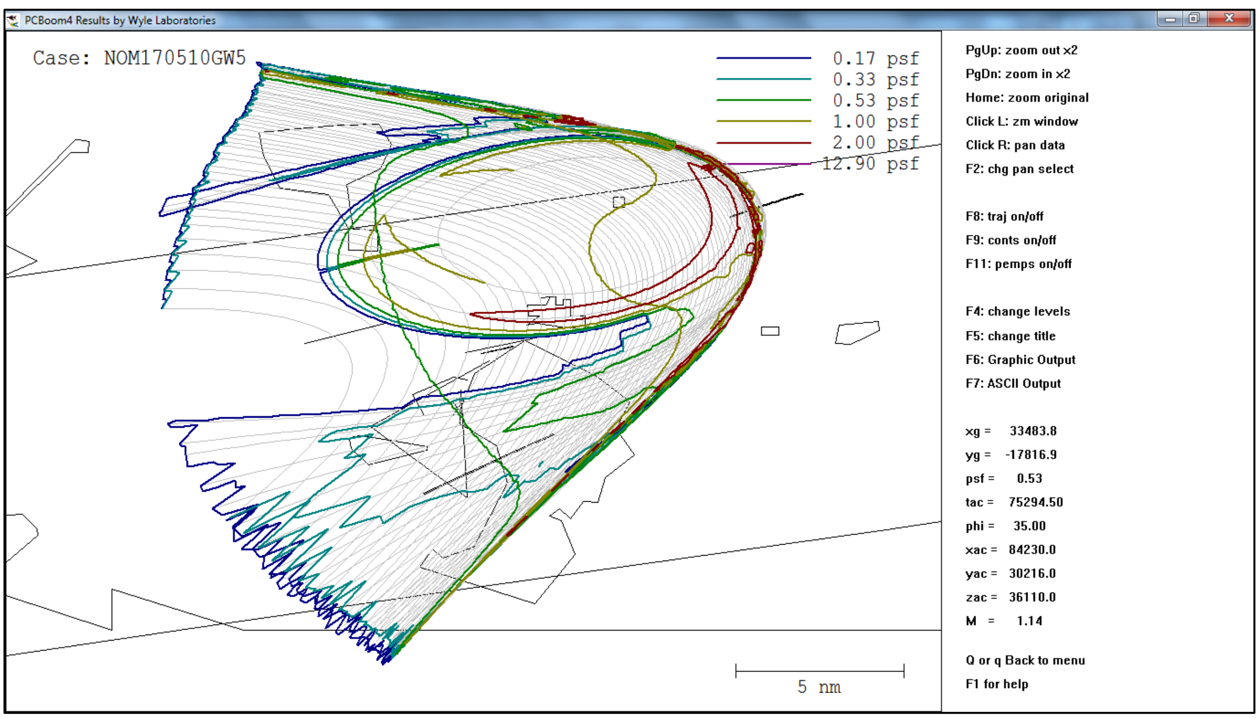


Figure 29 ***For booms between 1:30PM and 2:30PM local time:*** *m17051021z09forecast.atm weather file nom170510gw5 F-18 Dive Point 35 03' 46"N, 117 46' 47"W 2375 Grnd 34:57:04 -117:53:14 104 0.53*

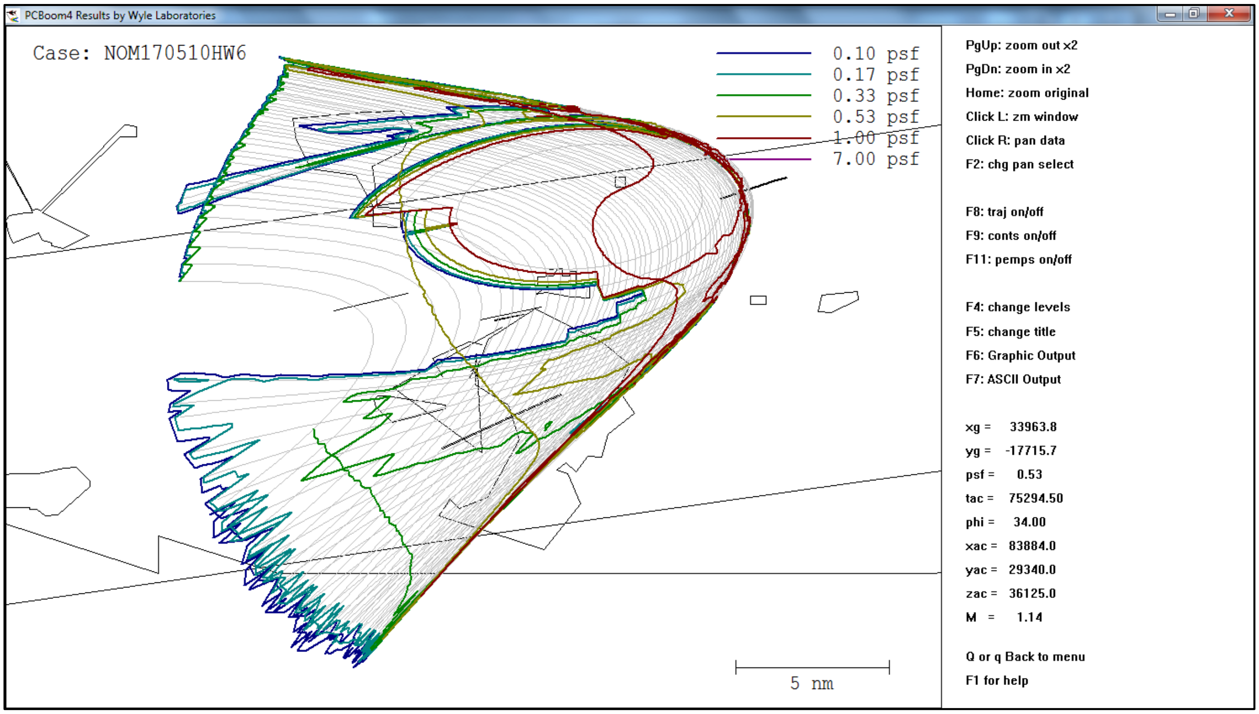


Figure 30 ***For booms between 2:30PM and 3:30PM local time:*** *m17051022z10forecast.atm weather file nom170510hw6 F-18 Dive Point 35 03' 38"N, 117 46' 52"W 2384 Grnd 34:57:04 -117:53:14 103 0.53*

IV. Thursday May 11th

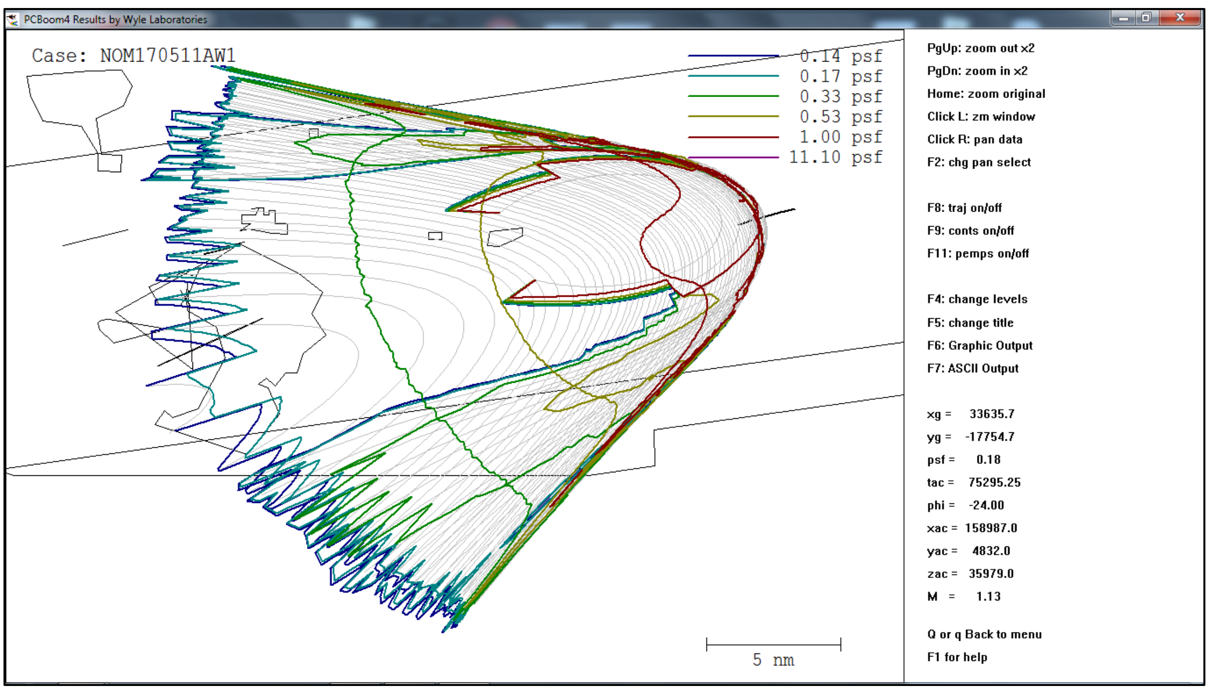


Figure 31 ***For booms before 08:30AM local time:*** *m17051115z09forecast.atm weather file nom170511aw1 Near Kramer Junction F-18 Dive Point 34 59' 54"N, 117 31' 33"W 2438 Grnd 34:57:04 -117:53:14 157 0.18*

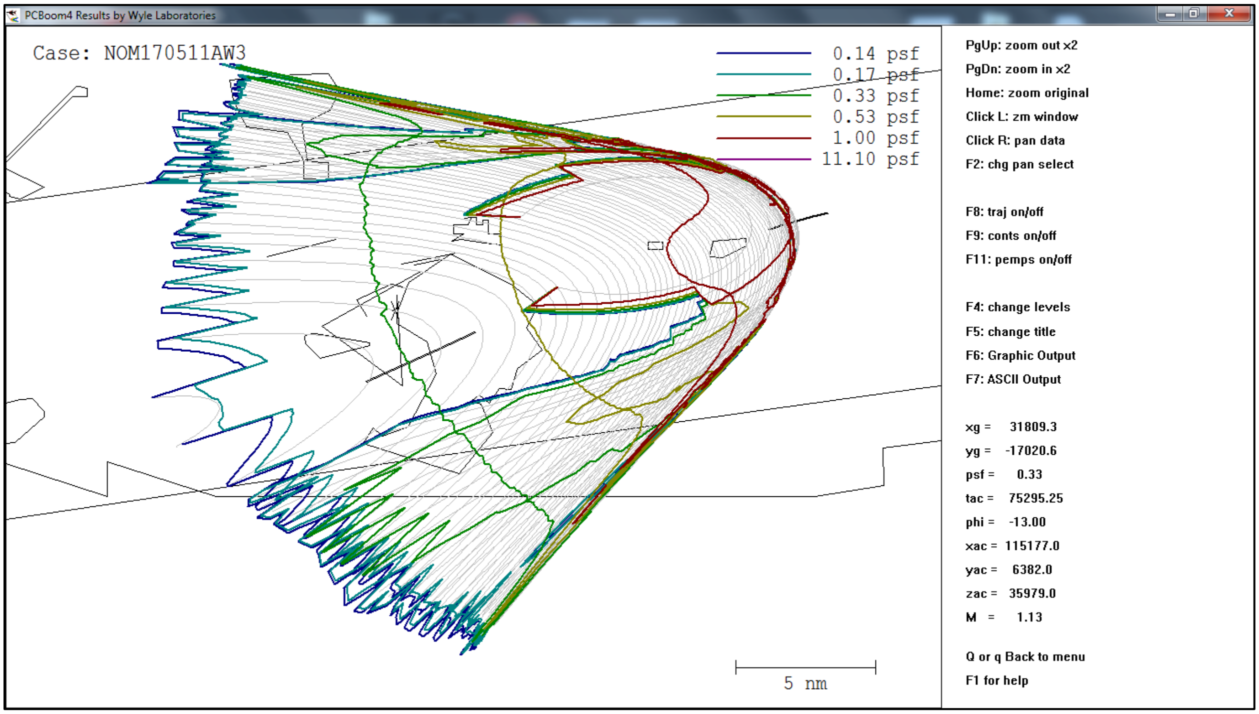


Figure 32 ***For booms before 08:30AM local time: nom170511aw3 West of Boron, south of the mine F-18 Dive Point 35 00' 09"N, 117 40' 21"W 2441 Grnd 34:57:04 -117:53:14 119 0.34***

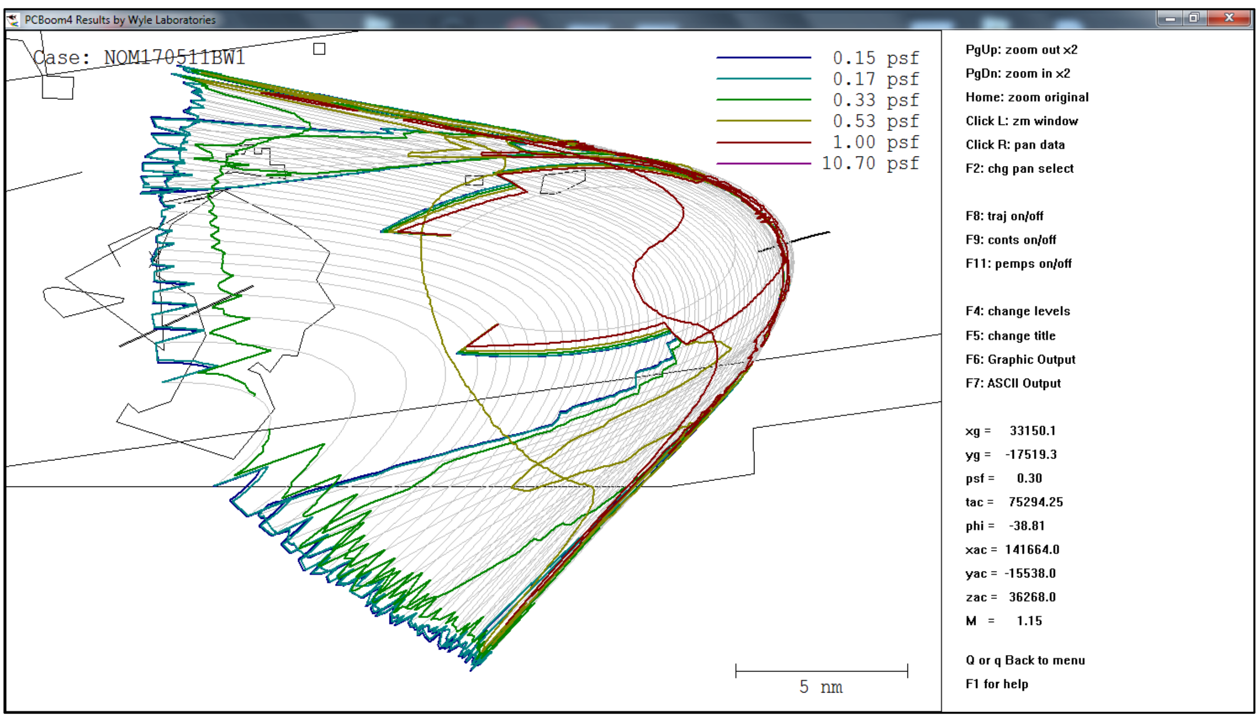


Figure 33 ***For booms between 08:30AM and 9:30AM local time: nom170511bw1 ***I have low confidence in this waypoint, only goes to 0.30 psf, at edge of carpet*** F-18 Dive Point 34 56' 30"N, 117 35' 11"W 2827 Grnd 34:57:04 -117:53:14 138 0.3***

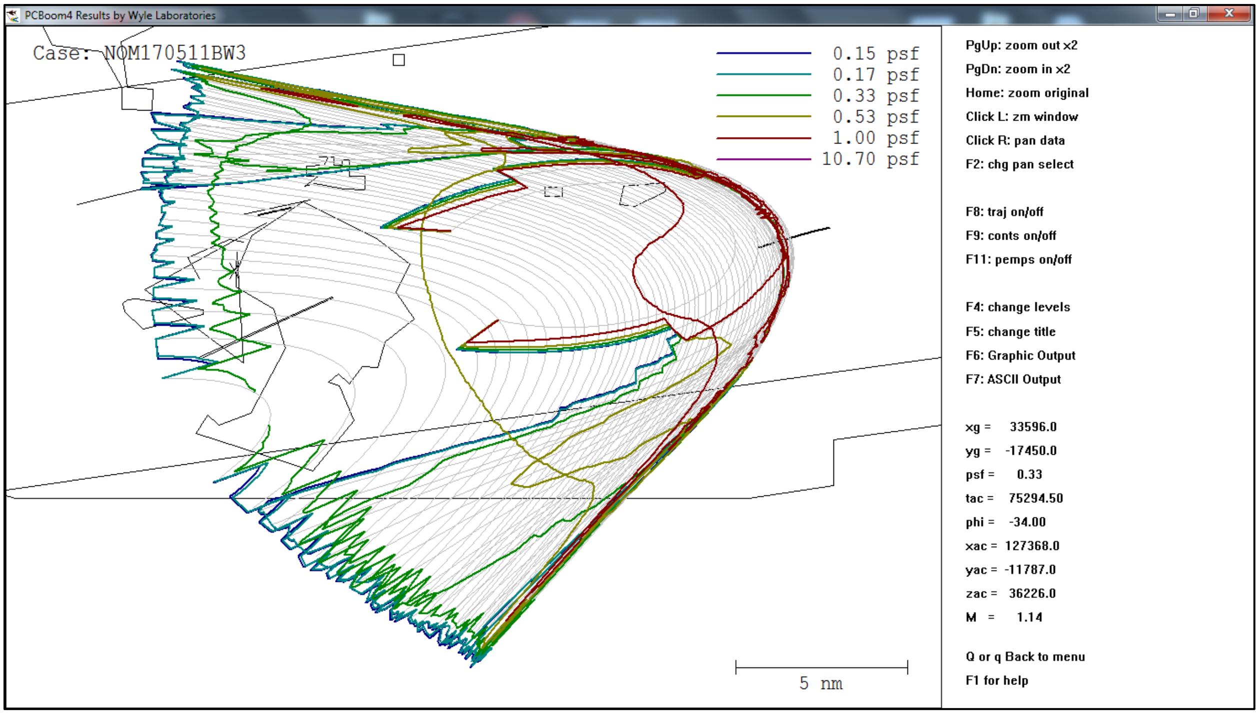


Figure 34 ***For booms between 08:30AM and 9:30AM local time: m17051116z10forecast.atm weather file om170511bw3 East of Rocket Lab, southeast of Boron F-18 Dive Point 34 57' 07"N, 117 38' 02"W 2667 Grnd 34:57:04 -117:53:14 126 0.33***

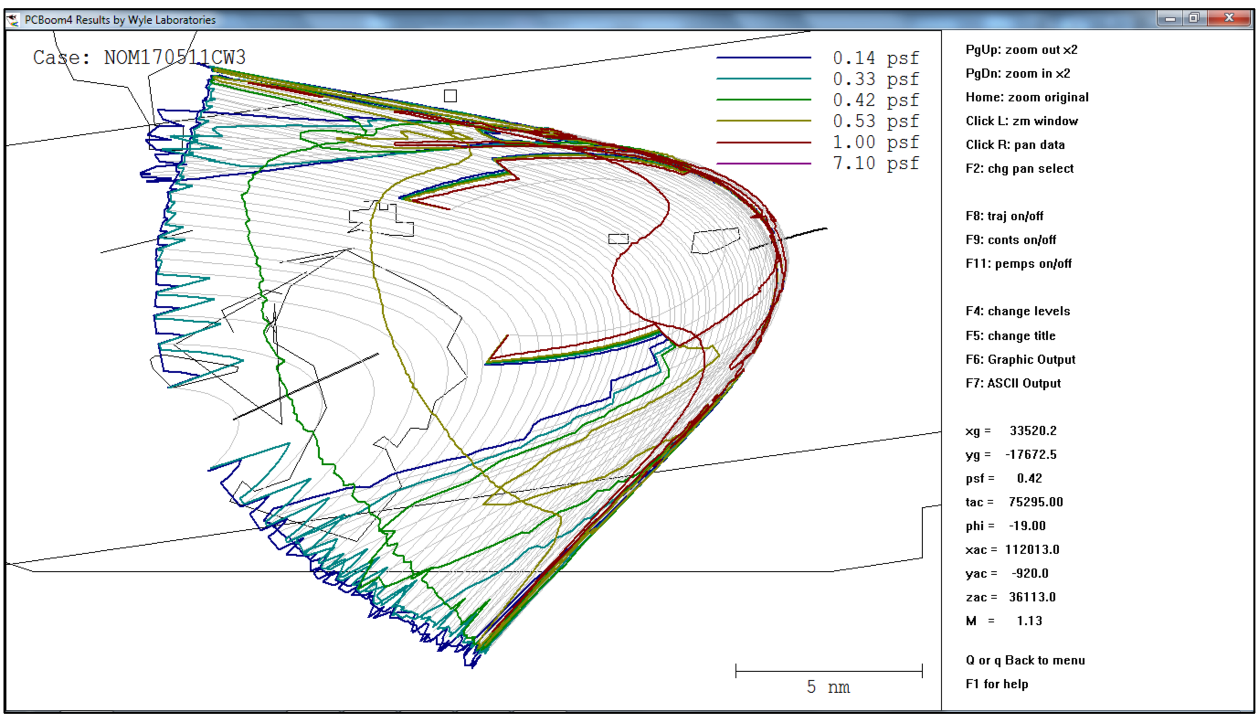


Figure 35 ***For booms before 10:30AM local time:*** *m17051117z05forecast.atm weather file nom170511cw3 F-18 Dive Point 34 58' 54"N, 117 41' 10"W 2459 Grnd 34:57:04 -117:53:14 114 0.42*

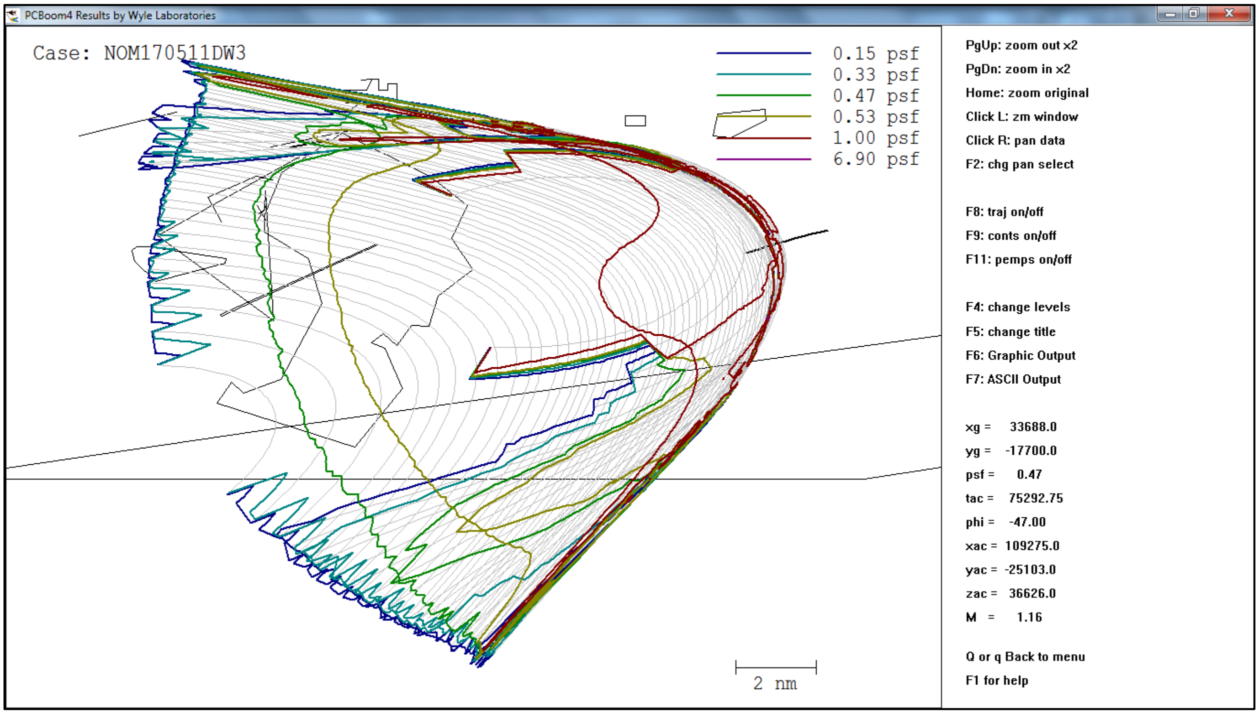
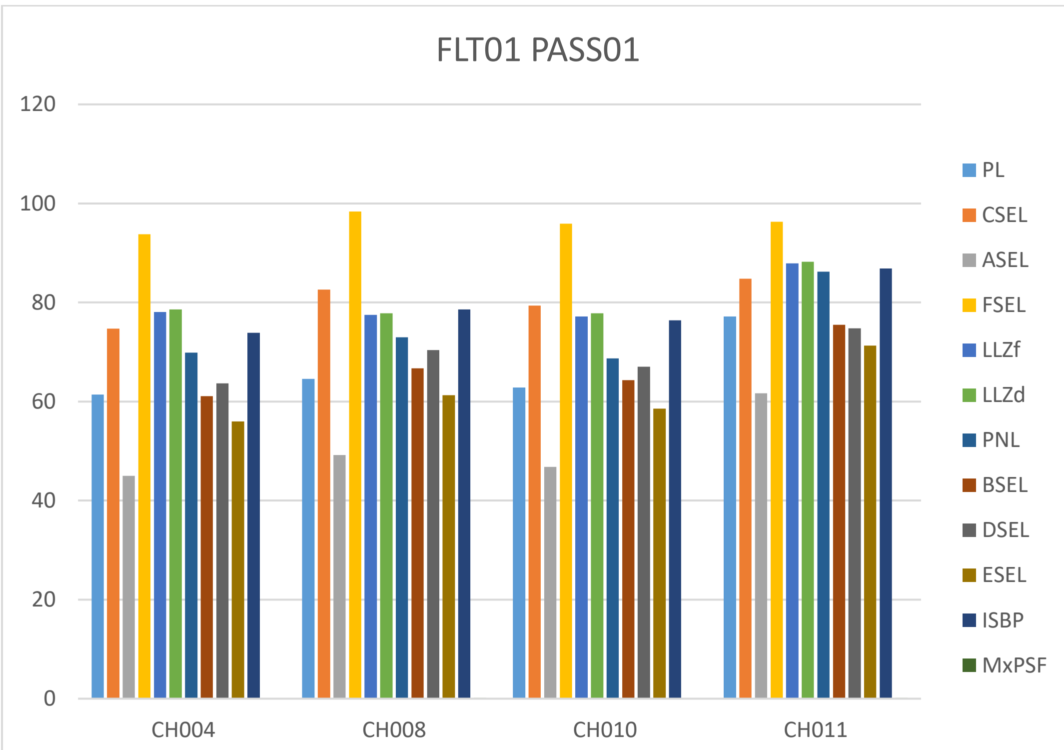


Figure 36 ***For all booms until 1:30PM local time:*** *m17051119z07forecast.atm weather file nom170511dw3 ***I'd use this waypoint for both times*** F-18 Dive Point 34 54' 49"N, 117 42' 08"W 2832 Grnd 34:57:04 -117:53:14 108 0.47*

C. Sonic Boom Metrics

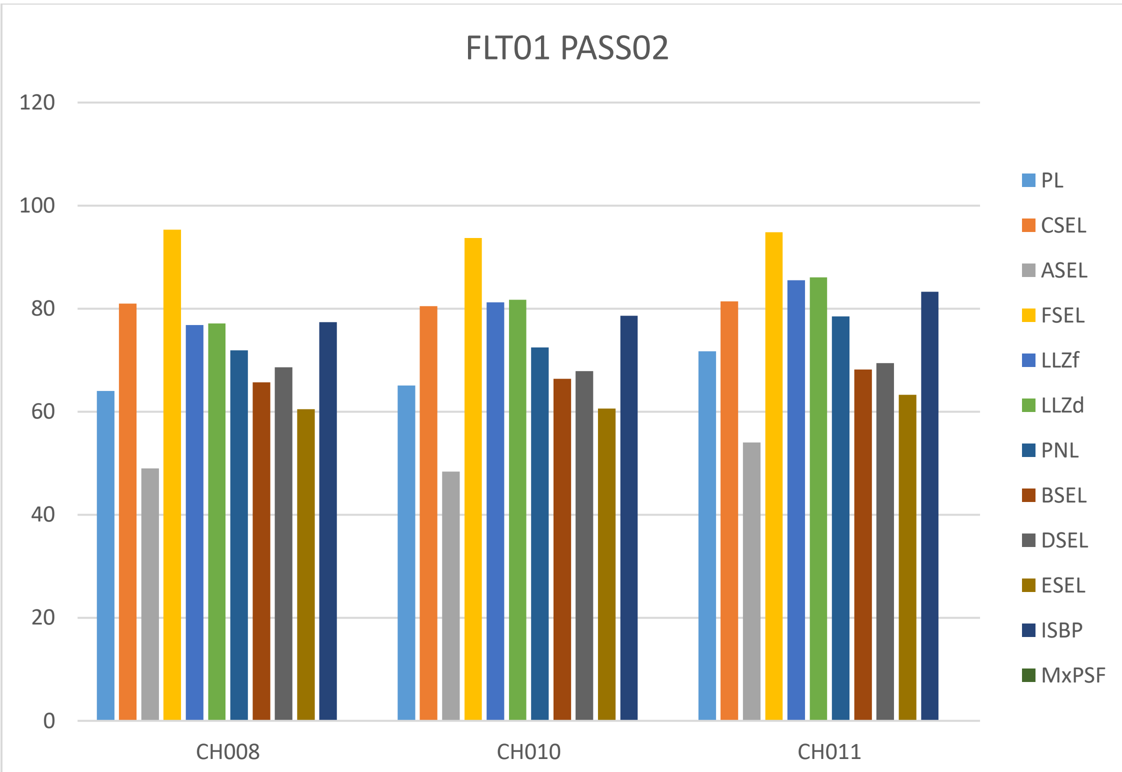
I. Flight 01 Pass01 09-May-2017 15:12:12.931 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	MxPSF	
61.4	74.7	45	93.8	78.1	78.6	69.9	61.1	63.7	56	73.9	0.08	CH004
64.6	82.6	49.2	98.4	77.5	77.8	73	66.7	70.4	61.3	78.6	0.14	CH008
62.8	79.4	46.8	95.9	77.2	77.8	68.7	64.3	67	58.6	76.4	0.09	CH010
77.2	84.8	61.7	96.3	87.9	88.2	86.2	75.5	74.8	71.3	86.9	0.15	CH011



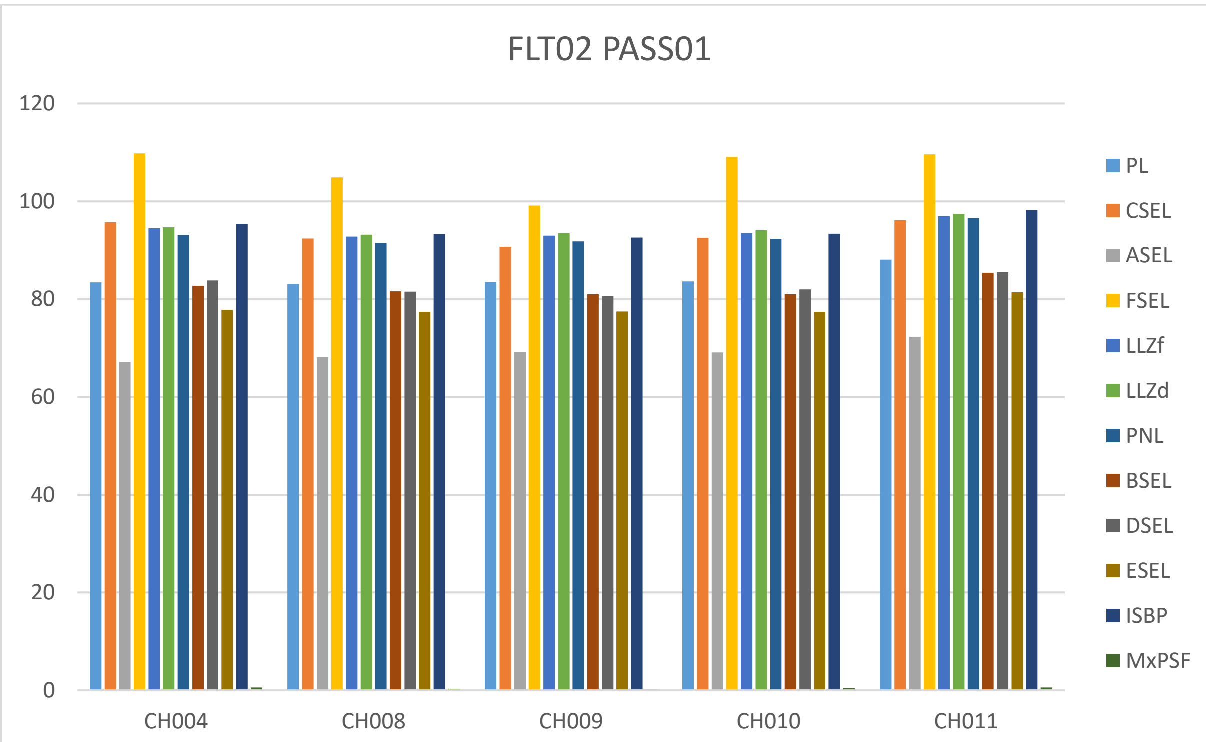
II. Flight 01 Pass02 09-May-2017 15:51:26.011 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	MxPSF	
64	81	49	95.3	76.8	77.1	71.9	65.7	68.6	60.5	77.4	0.1	CH008
65.1	80.5	48.4	93.7	81.2	81.7	72.5	66.4	67.9	60.6	78.6	0.09	CH010
71.7	81.4	54	94.8	85.5	86.1	78.5	68.2	69.4	63.3	83.3	0.1	CH011



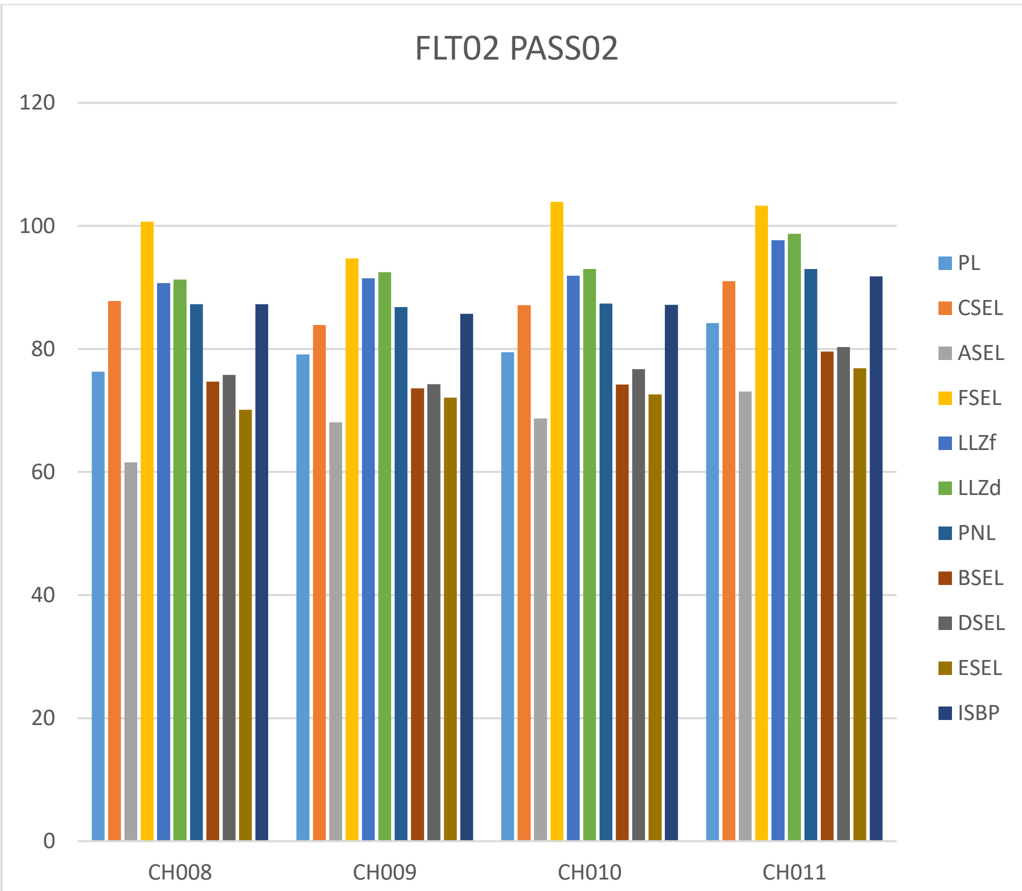
III. Flight 02 Pass01 09-May-2017 20:16:41.011 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	MxPSF	
83.4	95.7	67.1	109.8	94.5	94.7	93.1	82.7	83.8	77.8	95.4	0.55	CH004
83.1	92.4	68.1	104.9	92.8	93.2	91.5	81.6	81.5	77.4	93.3	0.33	CH008
83.5	90.7	69.2	99.1	93	93.5	91.8	81	80.6	77.5	92.6	0.21	CH009
83.6	92.5	69.1	109.1	93.5	94.1	92.3	81	82	77.4	93.4	0.43	CH010
88.1	96.1	72.3	109.6	97	97.4	96.6	85.4	85.5	81.4	98.2	0.57	CH011



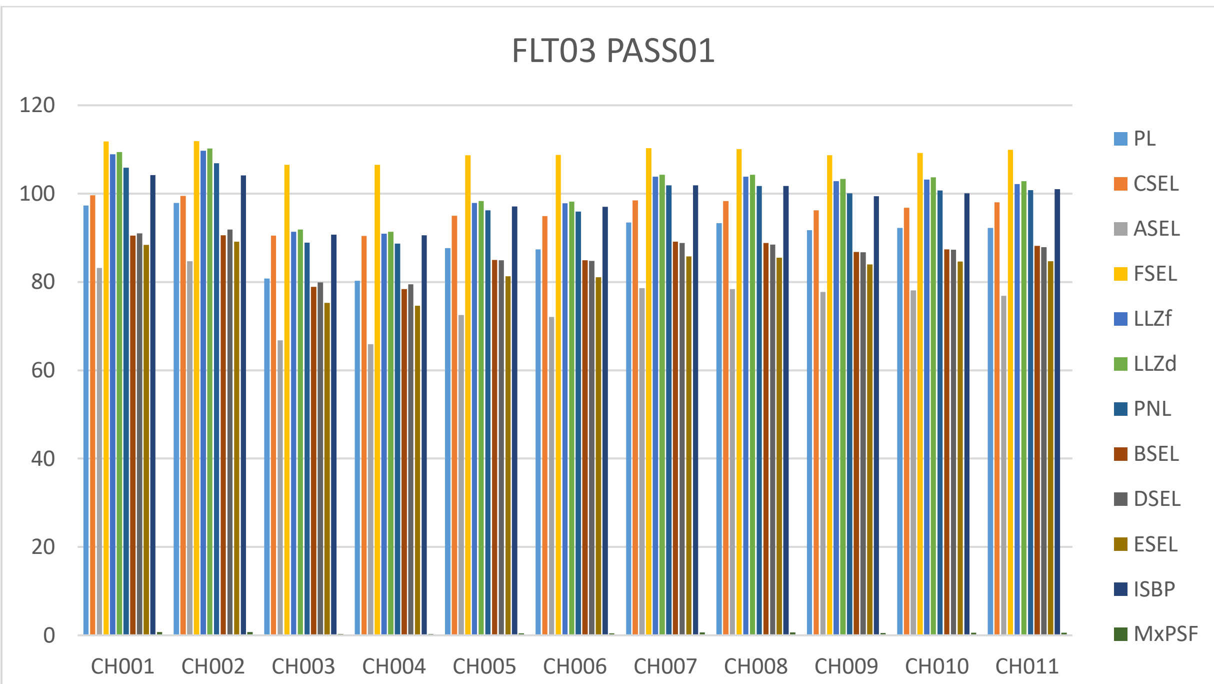
IV. Flight 02 Pass02 09-May-2017 20:39:01.940 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	
76.3	87.8	61.6	100.7	90.7	91.3	87.3	74.7	75.8	70.1	87.3	CH008
79.1	83.9	68.1	94.7	91.5	92.5	86.8	73.6	74.3	72.1	85.7	CH009
79.5	87.1	68.7	103.9	91.9	93	87.4	74.2	76.7	72.6	87.2	CH010
84.2	91	73.1	103.3	97.7	98.7	93	79.6	80.3	76.9	91.8	CH011



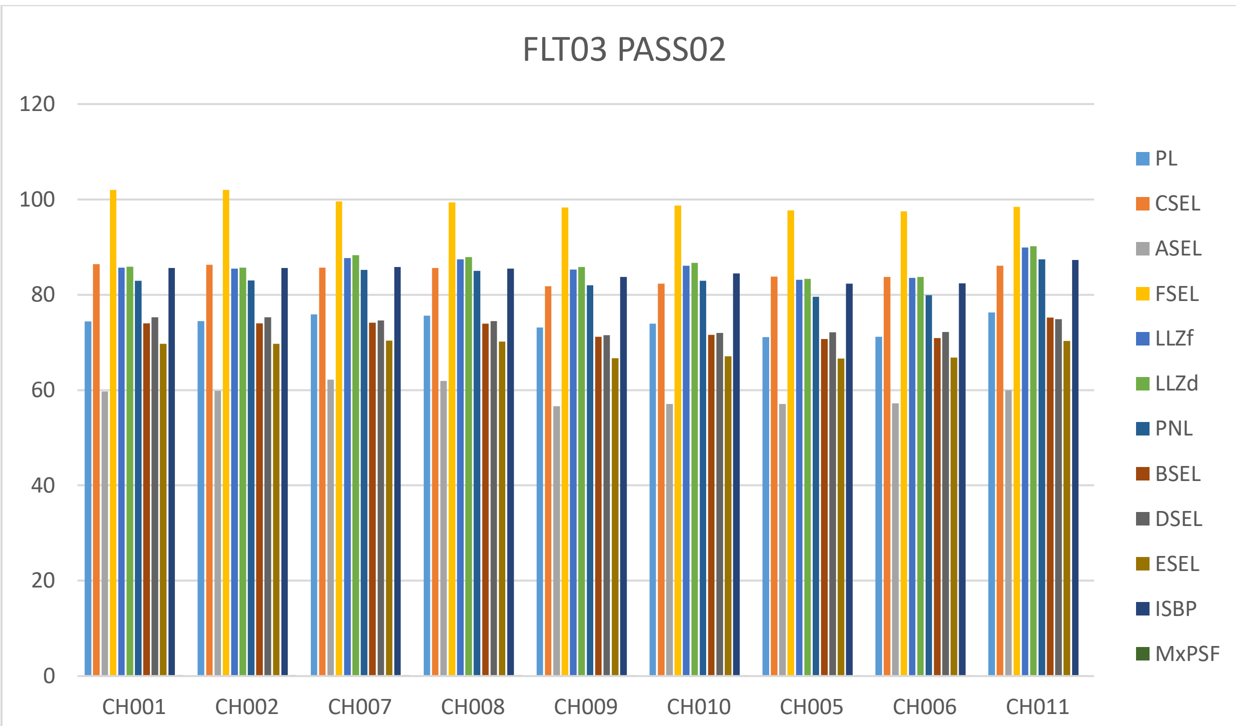
V. Flight 03 Pass01 10-May-2017 15:11:39.898 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	MxPSF	
97.3	99.6	83.2	111.8	108.9	109.4	105.9	90.5	91	88.4	104.2	0.77	CH001
97.9	99.5	84.7	111.9	109.7	110.2	106.9	90.6	91.9	89.1	104.1	0.77	CH002
80.8	90.5	66.8	106.5	91.4	91.9	88.9	78.9	79.9	75.3	90.7	0.31	CH003
80.3	90.4	65.9	106.5	90.9	91.4	88.7	78.4	79.5	74.6	90.6	0.31	CH004
87.7	95	72.5	108.7	97.9	98.3	96.2	85	84.9	81.3	97.1	0.46	CH005
87.4	94.9	72.1	108.8	97.8	98.2	95.9	84.9	84.8	81.1	97	0.45	CH006
93.5	98.5	78.6	110.3	103.8	104.3	101.9	89.1	88.8	85.8	101.9	0.68	CH007
93.3	98.3	78.4	110.1	103.8	104.3	101.7	88.8	88.5	85.5	101.7	0.66	CH008
91.7	96.2	77.7	108.7	102.8	103.3	100.1	86.8	86.7	84	99.4	0.55	CH009
92.2	96.8	78.1	109.2	103.2	103.7	100.7	87.4	87.3	84.6	100.1	0.58	CH010
92.2	98	76.9	109.9	102.2	102.8	100.8	88.2	87.9	84.7	101	0.62	CH011



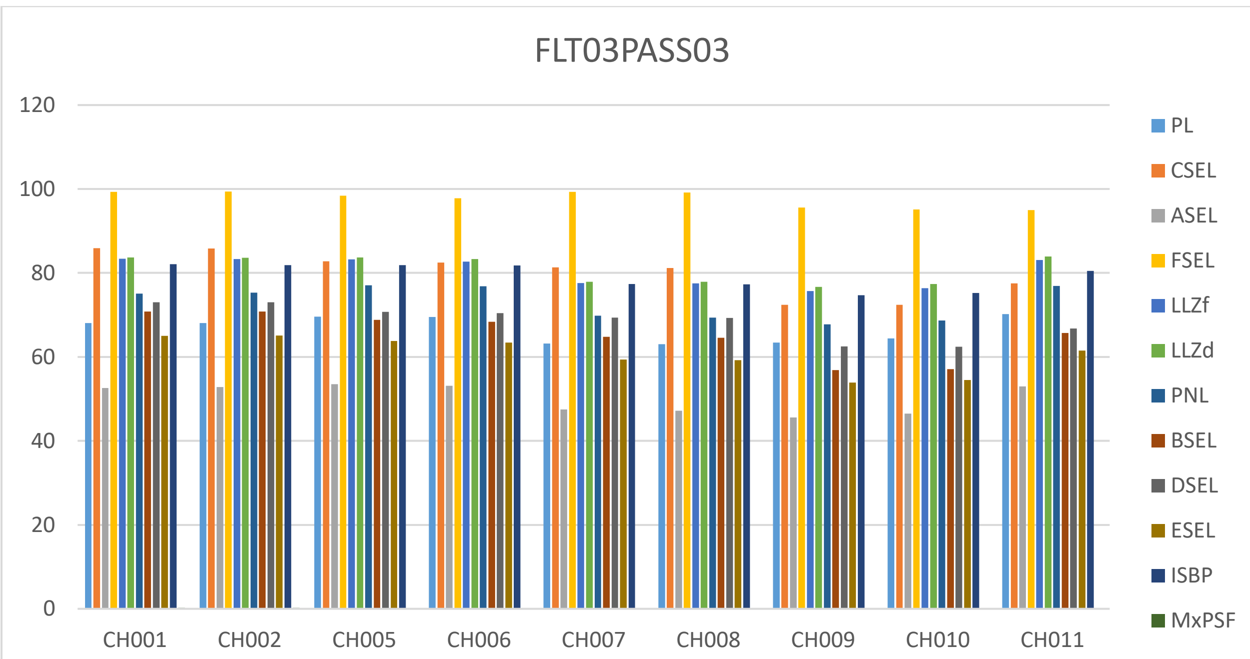
VI. Flight 03 Pass02 10-May-2017 15:37:19.994 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	MxPSF	
74.4	86.4	59.7	102	85.7	85.9	82.9	74	75.3	69.7	85.6	0.2	CH001
74.5	86.3	59.8	102	85.5	85.7	83	74	75.3	69.7	85.6	0.21	CH002
75.9	85.7	62.2	99.6	87.7	88.3	85.2	74.1	74.6	70.4	85.8	0.19	CH007
75.6	85.6	61.9	99.4	87.4	87.9	85	73.9	74.5	70.2	85.5	0.19	CH008
73.1	81.8	56.6	98.3	85.3	85.8	82	71.2	71.5	66.7	83.7	0.13	CH009
73.9	82.3	57.1	98.7	86.1	86.7	82.9	71.6	72	67.1	84.5	0.13	CH010
71.1	83.8	57.1	97.7	83.1	83.3	79.6	70.7	72.1	66.6	82.3	0.15	CH005
71.2	83.7	57.2	97.5	83.5	83.7	79.9	70.9	72.2	66.8	82.4	0.15	CH006
76.3	86.1	60	98.4	89.9	90.2	87.4	75.2	74.9	70.3	87.3	0.17	CH011



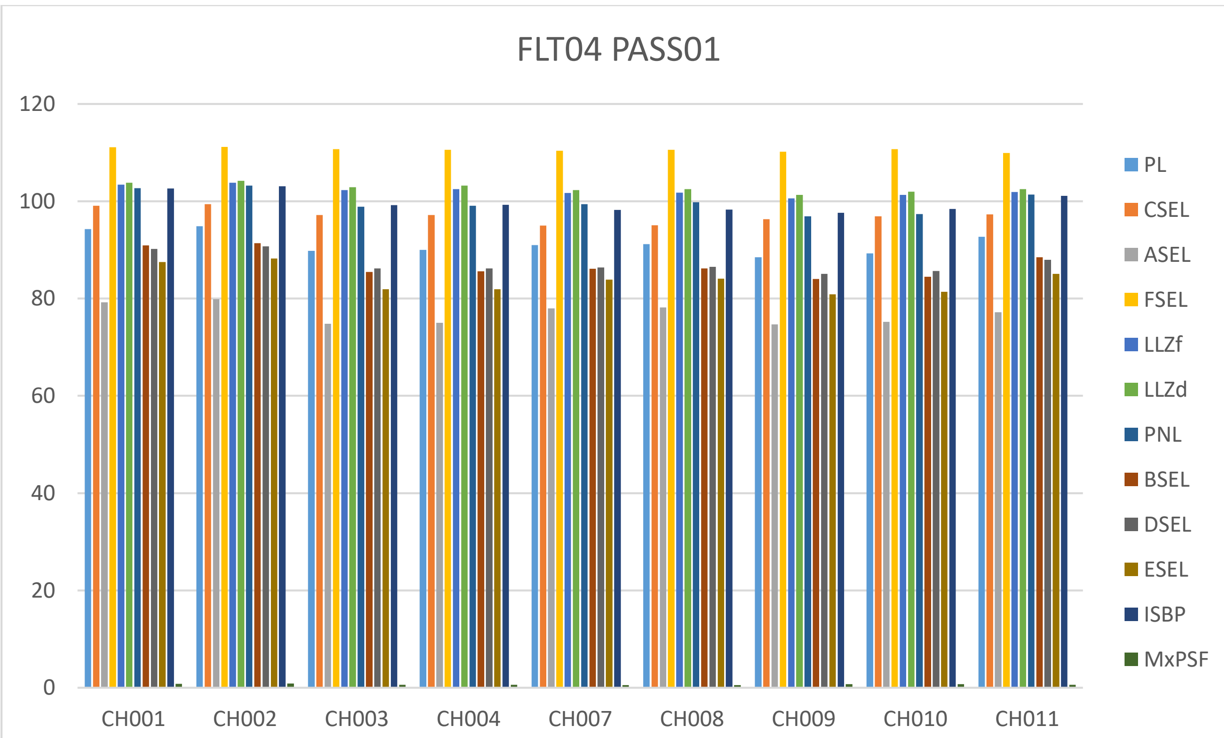
VII. Flight 03 Pass 03 10-May-2017 16:02:34.502 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	MxPSF	
68.1	85.9	52.6	99.3	83.4	83.7	75.1	70.8	73	65	82.1	0.2	CH001
68.1	85.8	52.8	99.4	83.3	83.6	75.3	70.8	73	65.1	81.9	0.19	CH002
69.6	82.8	53.5	98.4	83.2	83.7	77.1	68.8	70.7	63.8	81.9	0.13	CH005
69.5	82.5	53.1	97.8	82.7	83.3	76.8	68.4	70.4	63.4	81.8	0.13	CH006
63.2	81.3	47.5	99.3	77.6	77.9	69.8	64.8	69.4	59.4	77.4	0.14	CH007
63	81.2	47.2	99.2	77.5	77.9	69.4	64.6	69.3	59.2	77.3	0.14	CH008
63.4	72.4	45.6	95.6	75.7	76.7	67.8	56.9	62.5	53.9	74.7	0.09	CH009
64.4	72.4	46.5	95.1	76.4	77.4	68.7	57.1	62.4	54.5	75.2	0.07	CH010
70.2	77.5	53	95	83.1	83.9	76.9	65.7	66.8	61.5	80.5	0.08	CH011



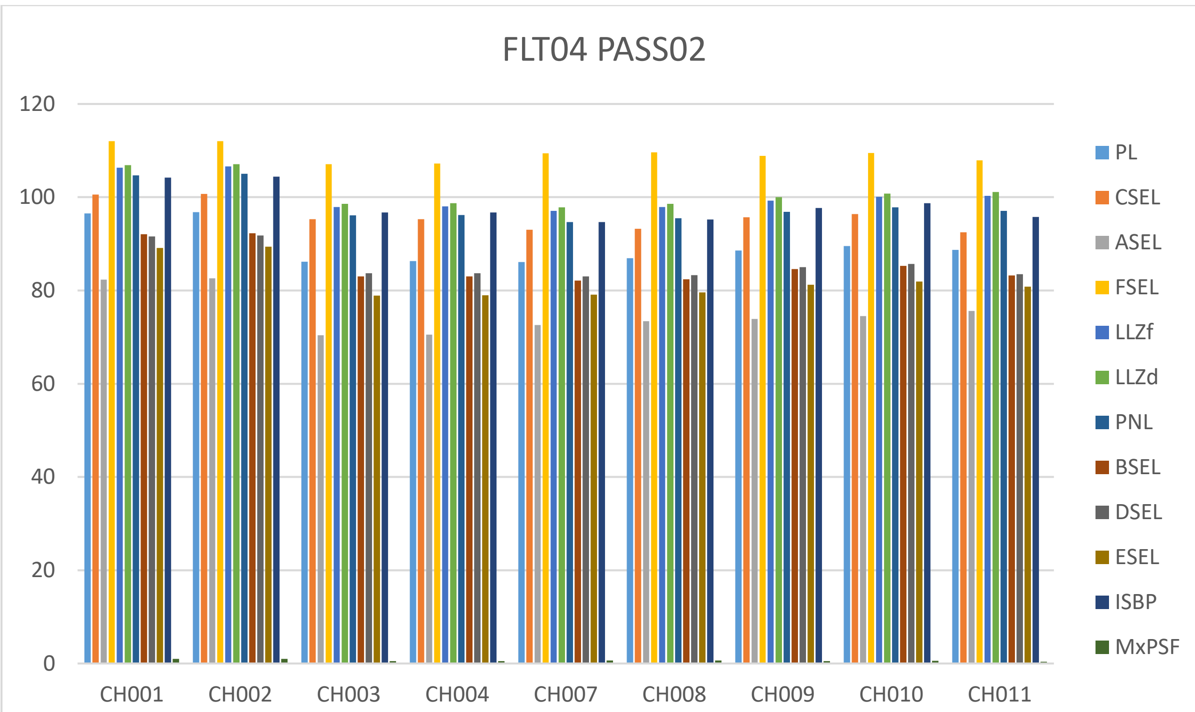
VIII. Flight 04 Pass01 10-May-2017 17:25:54.934 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	MxPSF	
94.3	99.1	79.2	111.1	103.4	103.8	102.7	90.9	90.2	87.5	102.6	0.82	CH001
94.9	99.4	79.9	111.2	103.8	104.2	103.2	91.4	90.7	88.2	103.1	0.85	CH002
89.8	97.2	74.8	110.7	102.3	102.9	98.9	85.5	86.2	81.9	99.2	0.62	CH003
90	97.2	75	110.6	102.5	103.2	99.1	85.6	86.2	81.9	99.3	0.63	CH004
91	95	78	110.4	101.7	102.3	99.4	86.1	86.4	83.9	98.2	0.51	CH007
91.2	95.1	78.2	110.6	101.8	102.5	99.8	86.2	86.5	84.1	98.3	0.51	CH008
88.5	96.3	74.7	110.2	100.6	101.3	96.9	84	85.1	80.9	97.6	0.73	CH009
89.3	96.9	75.2	110.7	101.3	102	97.4	84.5	85.7	81.4	98.4	0.77	CH010
92.7	97.3	77.2	109.9	101.9	102.5	101.4	88.5	88	85.1	101.1	0.62	CH011



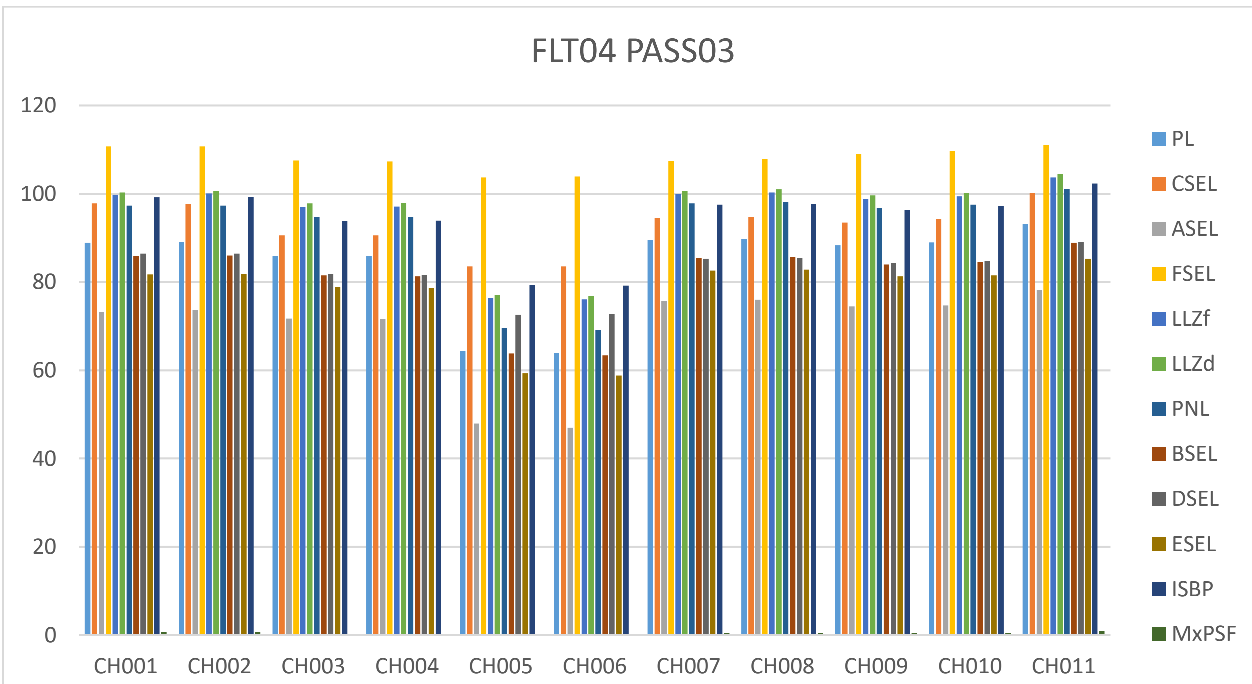
IX. Flight 04 Pass 02 10-May-2017 17:59:55.904 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	MxPSF	
96.5	100.6	82.3	112	106.3	106.9	104.7	92.1	91.6	89.1	104.2	0.99	CH001
96.8	100.7	82.6	112	106.6	107.1	105	92.3	91.8	89.4	104.4	1.02	CH002
86.2	95.3	70.4	107.1	97.9	98.6	96.1	83	83.7	78.9	96.7	0.5	CH003
86.3	95.3	70.5	107.2	98	98.7	96.2	83	83.7	79	96.7	0.5	CH004
86.1	93	72.6	109.4	97.1	97.8	94.7	82.1	83	79.1	94.7	0.63	CH007
86.9	93.2	73.4	109.6	97.9	98.6	95.5	82.4	83.3	79.6	95.2	0.65	CH008
88.6	95.7	73.9	108.9	99.3	100	96.9	84.6	85	81.2	97.7	0.54	CH009
89.5	96.4	74.5	109.5	100.1	100.8	97.8	85.3	85.7	81.9	98.7	0.58	CH010
88.7	92.5	75.6	107.9	100.3	101.1	97.1	83.2	83.5	80.8	95.8	0.35	CH011



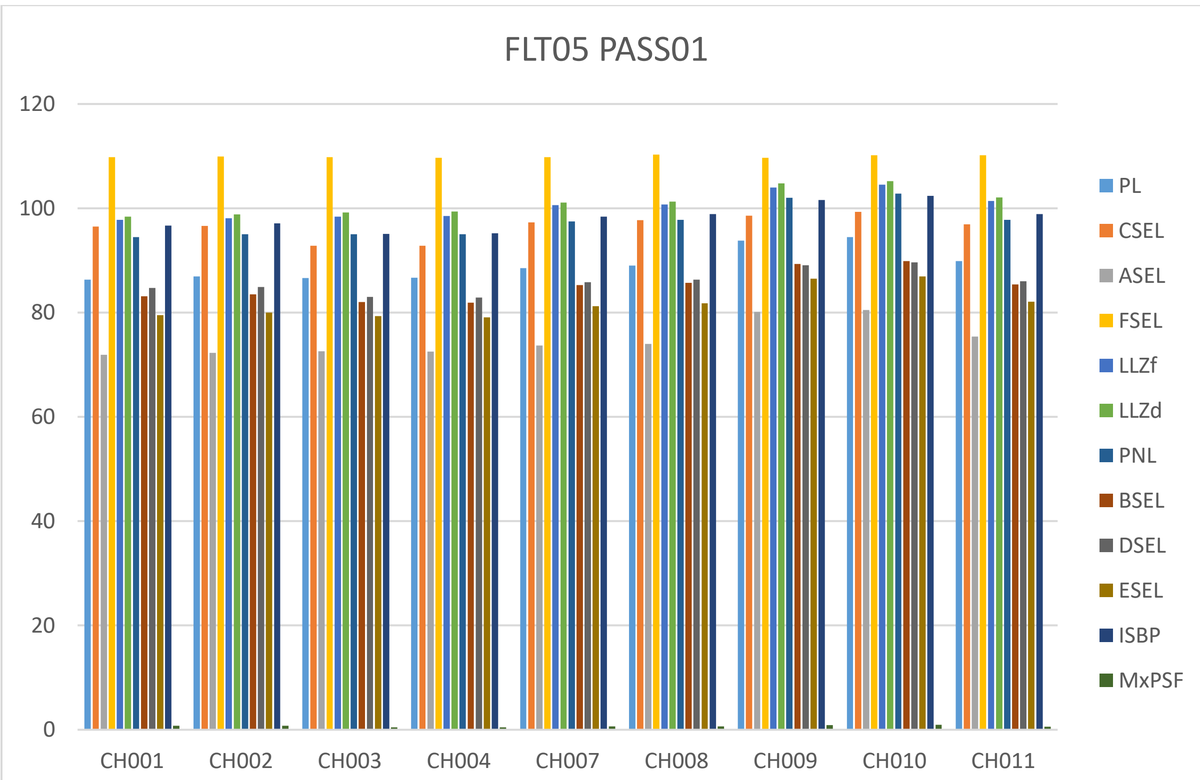
X. Flight 04 Pass03 10-May-2017 18:20:45.976 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	MxPSF	
88.9	97.8	73.2	110.7	99.8	100.3	97.3	85.9	86.4	81.7	99.2	0.73	CH001
89.1	97.7	73.6	110.7	100.1	100.6	97.3	86	86.4	81.9	99.3	0.73	CH002
89.5	94.5	75.7	107.4	99.9	100.6	97.8	85.5	85.3	82.6	97.5	0.42	CH007
89.8	94.8	76	107.8	100.3	101	98.1	85.7	85.5	82.8	97.7	0.44	CH008
88.3	93.5	74.5	109	98.8	99.6	96.7	84	84.3	81.3	96.3	0.52	CH009
89	94.3	74.7	109.6	99.4	100.2	97.5	84.5	84.8	81.5	97.2	0.55	CH010
93.1	100.2	78.2	111	103.7	104.4	101.1	88.9	89.1	85.3	102.3	0.89	CH011
64.4	83.5	47.9	103.7	76.4	77.1	69.6	63.8	72.6	59.3	79.3	0.21	CH005
63.9	83.5	47	103.9	76.1	76.8	69.1	63.4	72.7	58.8	79.2	0.22	CH006
85.9	90.6	71.7	107.5	97	97.8	94.7	81.5	81.8	78.8	93.8	0.28	CH003
85.9	90.6	71.6	107.3	97.1	97.9	94.7	81.3	81.6	78.6	93.9	0.29	CH004



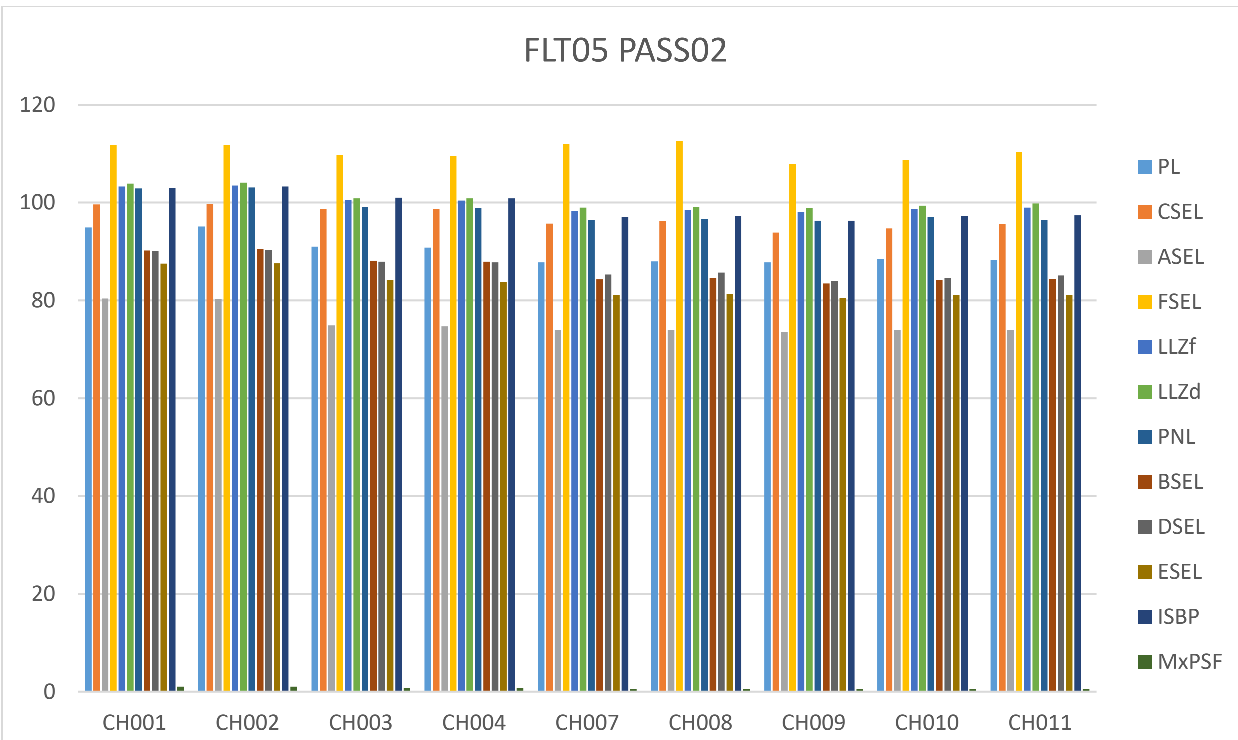
XI. Flight 05 Pass01 10-May-2017 19:15:55.008 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	MxPSF	
86.3	96.5	71.9	109.8	97.8	98.4	94.5	83.1	84.7	79.5	96.7	0.76	CH001
86.9	96.6	72.3	109.9	98.1	98.8	95	83.5	84.9	80	97.1	0.79	CH002
86.6	92.8	72.6	109.8	98.4	99.2	95	82	83	79.3	95.1	0.46	CH003
86.7	92.8	72.5	109.7	98.5	99.4	95	81.9	82.9	79.1	95.2	0.46	CH004
88.5	97.3	73.7	109.8	100.6	101.1	97.5	85.3	85.8	81.2	98.4	0.63	CH007
89	97.7	74	110.3	100.7	101.3	97.8	85.7	86.3	81.8	98.9	0.65	CH008
93.8	98.6	80.1	109.7	104	104.8	102	89.3	89.1	86.5	101.6	0.88	CH009
94.5	99.3	80.5	110.2	104.5	105.2	102.8	89.9	89.6	86.9	102.4	0.93	CH010
89.9	96.9	75.4	110.2	101.4	102.1	97.8	85.4	86	82.1	98.9	0.61	CH011



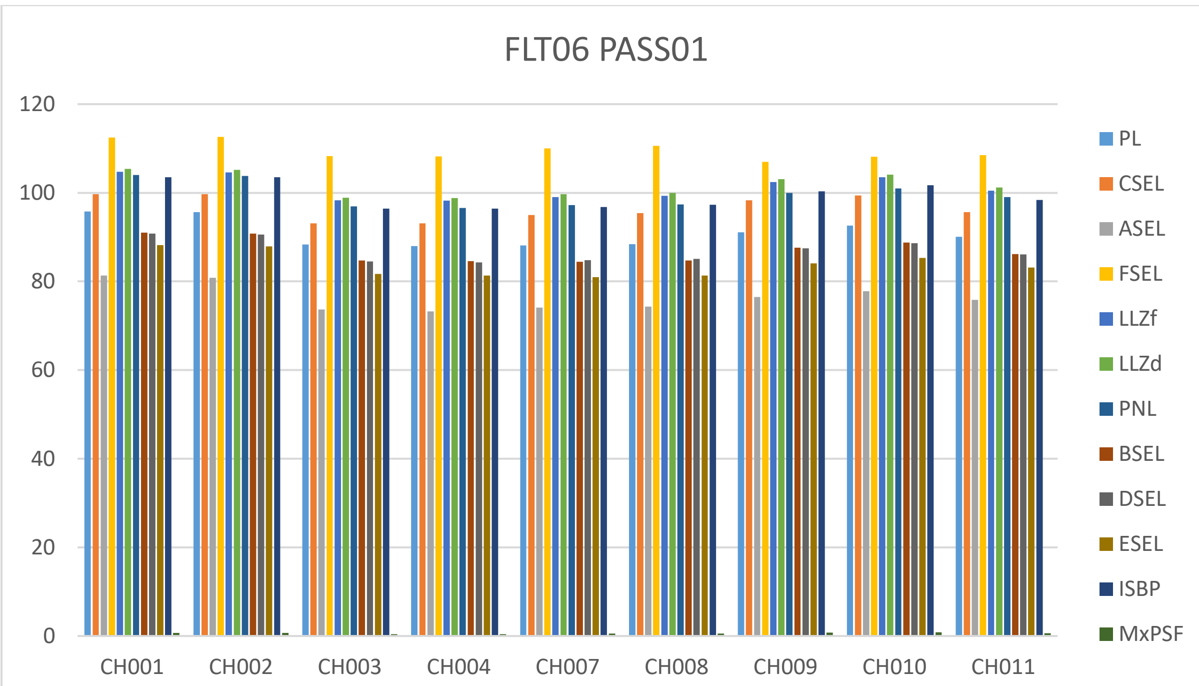
XII. Flight 05 Pass02 10-May-2017 20:01:16.531 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	MxPSF	
94.9	99.6	80.4	111.8	103.3	103.9	102.9	90.2	90.1	87.5	103	1.02	CH001
95.1	99.7	80.3	111.8	103.5	104.1	103.1	90.5	90.3	87.6	103.3	1.05	CH002
91	98.7	74.9	109.7	100.5	100.9	99.1	88.1	87.9	84.1	101	0.74	CH003
90.8	98.7	74.7	109.5	100.4	100.9	98.9	87.9	87.8	83.8	100.9	0.73	CH004
87.8	95.7	73.9	112	98.3	99	96.5	84.3	85.3	81.1	97	0.55	CH007
88	96.2	73.9	112.6	98.5	99.1	96.7	84.6	85.7	81.3	97.3	0.58	CH008
87.8	93.9	73.5	107.9	98.1	98.9	96.3	83.5	83.9	80.5	96.3	0.49	CH009
88.5	94.7	74	108.7	98.7	99.4	97	84.2	84.6	81.1	97.2	0.53	CH010
88.3	95.6	73.9	110.3	99	99.8	96.5	84.4	85.1	81.1	97.4	0.55	CH011



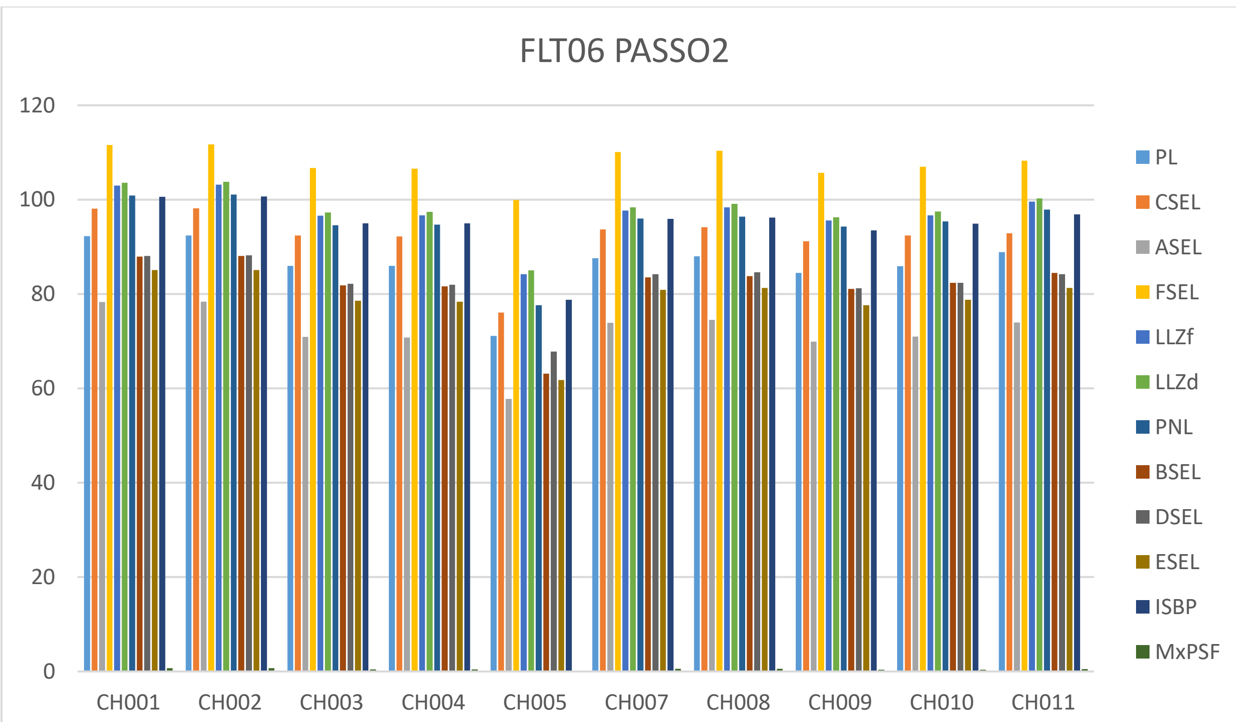
XIII. Flight 06 Pass01 10-May-2017 21:08:20.002 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	MxPSF	
95.8	99.7	81.3	112.5	104.7	105.4	104	91	90.8	88.2	103.5	0.72	CH001
95.6	99.7	80.8	112.6	104.6	105.2	103.8	90.8	90.6	87.9	103.5	0.73	CH002
88.3	93.1	73.7	108.3	98.3	98.9	96.9	84.7	84.5	81.7	96.4	0.41	CH003
88	93.1	73.2	108.2	98.2	98.8	96.6	84.6	84.3	81.3	96.4	0.4	CH004
88.1	95	74.1	110	99	99.7	97.2	84.4	84.8	81	96.8	0.56	CH007
88.4	95.4	74.3	110.6	99.3	100	97.4	84.7	85.1	81.3	97.3	0.58	CH008
91.1	98.3	76.5	107	102.4	103.1	100	87.6	87.5	84.1	100.3	0.75	CH009
92.6	99.4	77.8	108.1	103.5	104.1	101	88.8	88.6	85.3	101.7	0.85	CH010
90.1	95.6	75.8	108.5	100.5	101.2	99	86.2	86.1	83.1	98.4	0.65	CH011



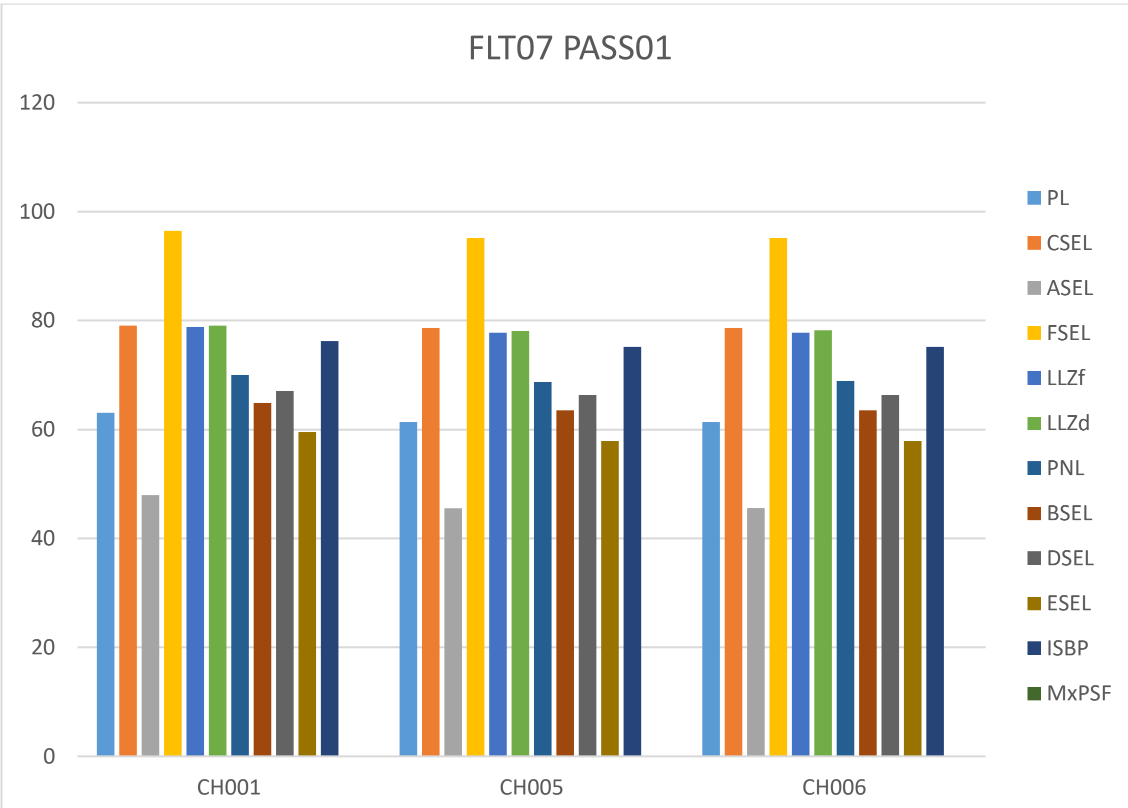
XIV. Flight 06 Pass02 10-May-2017 21:49:22.997 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	MxPSF	
92.3	98.1	78.3	111.6	103	103.6	100.9	87.9	88.1	85.1	100.6	0.7	CH001
92.4	98.2	78.4	111.7	103.2	103.8	101.1	88.1	88.2	85.1	100.7	0.7	CH002
86	92.4	70.9	106.7	96.6	97.3	94.6	81.8	82.2	78.6	95	0.4	CH003
86	92.2	70.8	106.6	96.7	97.4	94.7	81.6	82	78.4	95	0.4	CH004
71.1	76.1	57.8	99.9	84.2	85	77.6	63.1	67.8	61.8	78.8	0.12	CH005
87.6	93.7	73.9	110.1	97.7	98.4	96	83.5	84.2	80.9	95.9	0.57	CH007
88	94.2	74.5	110.4	98.4	99.1	96.4	83.8	84.6	81.3	96.2	0.58	CH008
84.5	91.2	69.9	105.7	95.6	96.3	94.3	81.1	81.2	77.6	93.5	0.34	CH009
85.9	92.4	71	107	96.7	97.5	95.4	82.4	82.4	78.8	94.9	0.38	CH010
88.9	92.9	74	108.3	99.6	100.3	97.9	84.5	84.2	81.3	96.9	0.47	CH011



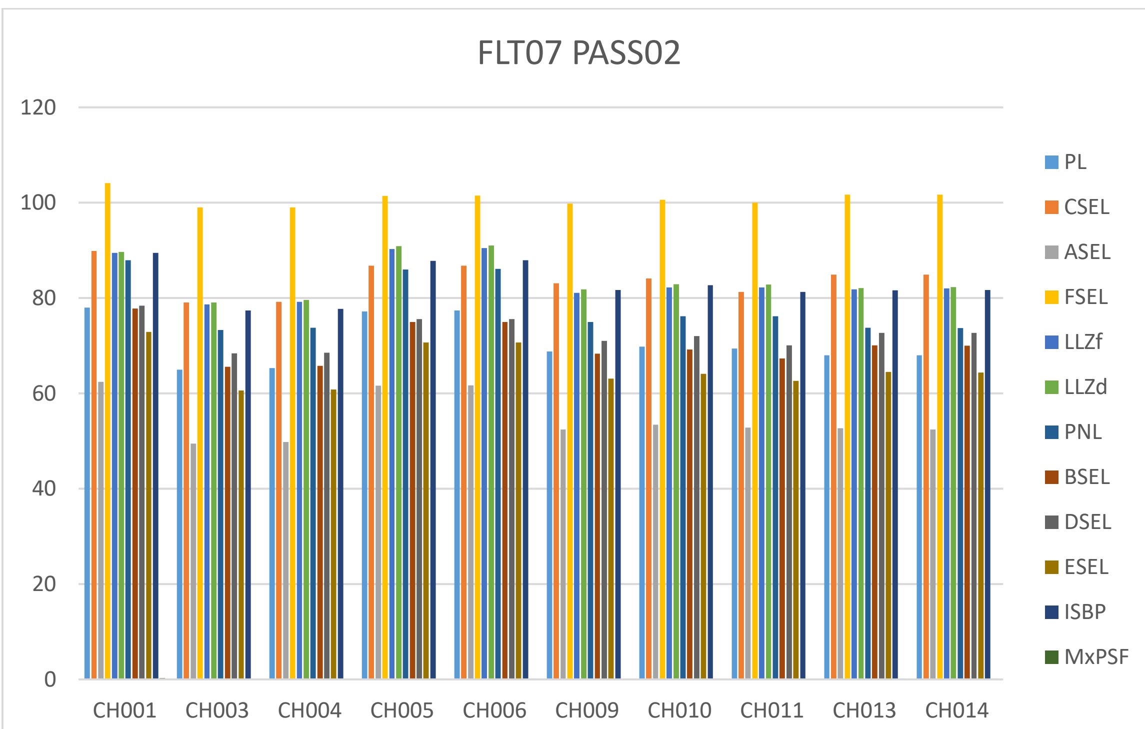
XV. Flight 07 Pass01 11-May-2017 15:08:31.918 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	MxPSF	
63.1	79.1	47.9	96.5	78.8	79.1	70	64.9	67.1	59.5	76.2	0.09	CH001
61.3	78.6	45.5	95.1	77.8	78.1	68.7	63.5	66.3	57.9	75.2	0.05	CH005
61.4	78.6	45.6	95.1	77.8	78.2	68.9	63.5	66.3	57.9	75.2	0.05	CH006



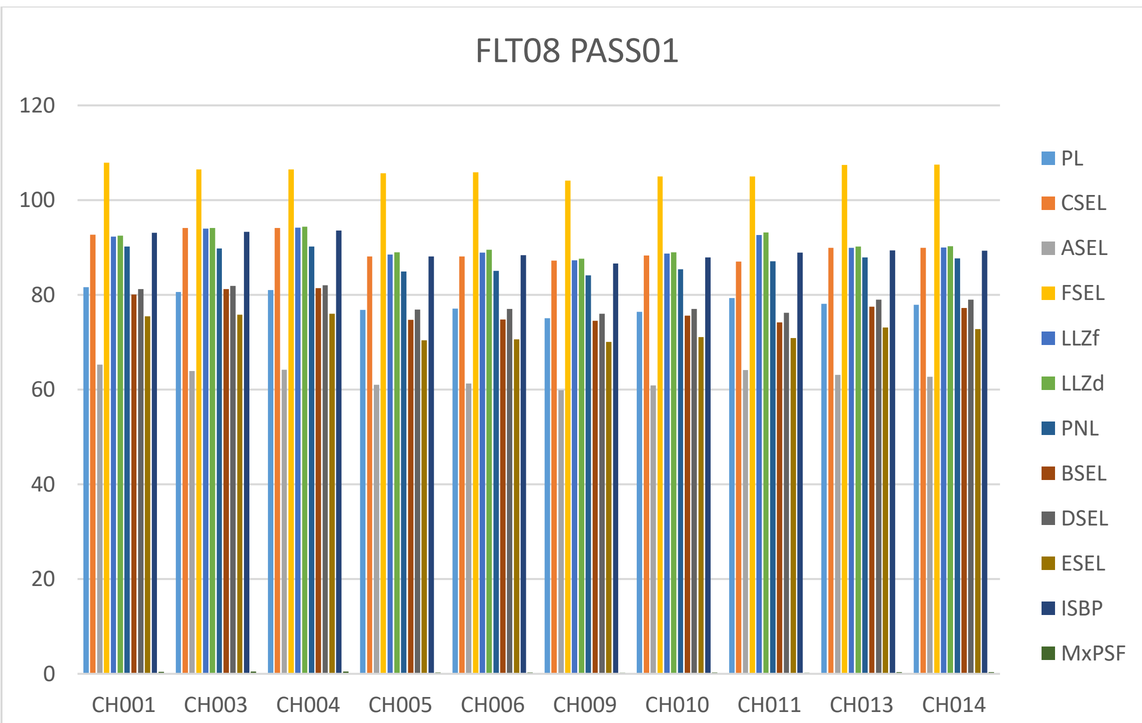
XVI. Flight 07 Pass02 11-May-2017 15:51:34.031 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	MxPSF	
78	89.9	62.4	104.1	89.5	89.7	87.9	77.8	78.4	72.9	89.5	0.26	CH001
65	79.1	49.5	99	78.7	79.1	73.3	65.6	68.4	60.6	77.4	0.1	CH003
65.3	79.2	49.8	99	79.2	79.6	73.8	65.8	68.5	60.8	77.7	0.1	CH004
77.2	86.8	61.6	101.4	90.3	90.9	86	75	75.6	70.7	87.8	0.19	CH005
77.4	86.8	61.7	101.5	90.5	91	86.1	75	75.6	70.7	87.9	0.19	CH006
68.8	83.1	52.4	99.8	81.1	81.8	75	68.3	71	63.1	81.7	0.16	CH009
69.8	84.1	53.4	100.6	82.2	82.9	76.2	69.2	72	64.1	82.7	0.17	CH010
69.4	81.3	52.8	100	82.2	82.8	76.2	67.3	70.1	62.6	81.3	0.15	CH011
68	84.9	52.7	101.7	81.8	82.1	73.8	70.1	72.7	64.5	81.6	0.19	CH013
68	84.9	52.4	101.7	82	82.3	73.7	70	72.7	64.4	81.7	0.19	CH014



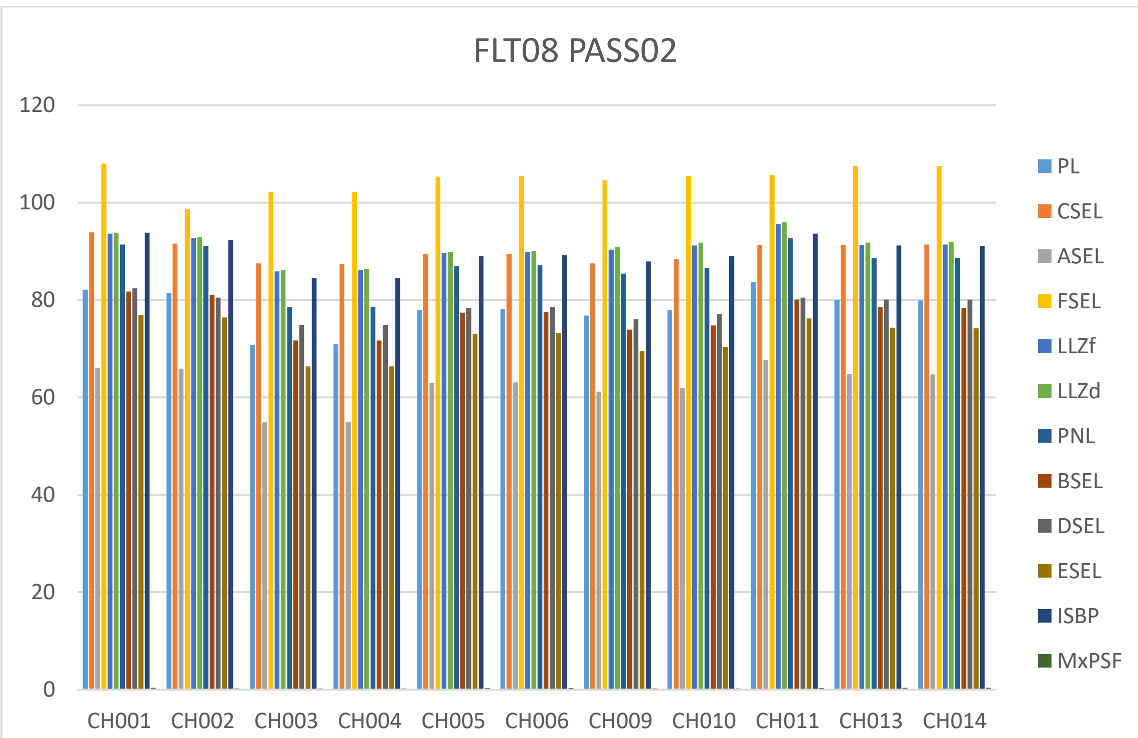
XVII. FLT08 Pass01 11-May-2017 16:40:10.970 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	MxPSF	
81.6	92.7	65.3	107.9	92.3	92.5	90.2	80.1	81.2	75.5	93.1	0.43	CH001
80.6	94.1	63.9	106.5	94	94.1	89.8	81.2	81.9	75.8	93.3	0.46	CH003
81	94.1	64.2	106.5	94.2	94.4	90.2	81.4	82	76	93.6	0.47	CH004
76.8	88.1	61	105.7	88.5	89	84.9	74.7	76.9	70.4	88.1	0.3	CH005
77.1	88.1	61.3	105.9	88.9	89.5	85.1	74.8	77	70.6	88.4	0.31	CH006
75.1	87.2	59.9	104.1	87.3	87.6	84.1	74.5	76	70.1	86.6	0.24	CH009
76.4	88.3	60.9	105	88.7	89	85.4	75.6	77	71.1	87.9	0.26	CH010
79.3	87	64.1	105	92.6	93.2	87.1	74.2	76.2	70.9	88.9	0.23	CH011
78.1	89.9	63.1	107.4	89.9	90.2	87.9	77.5	79	73.1	89.4	0.38	CH013
77.9	89.9	62.7	107.5	90	90.3	87.7	77.2	79	72.8	89.3	0.37	CH014



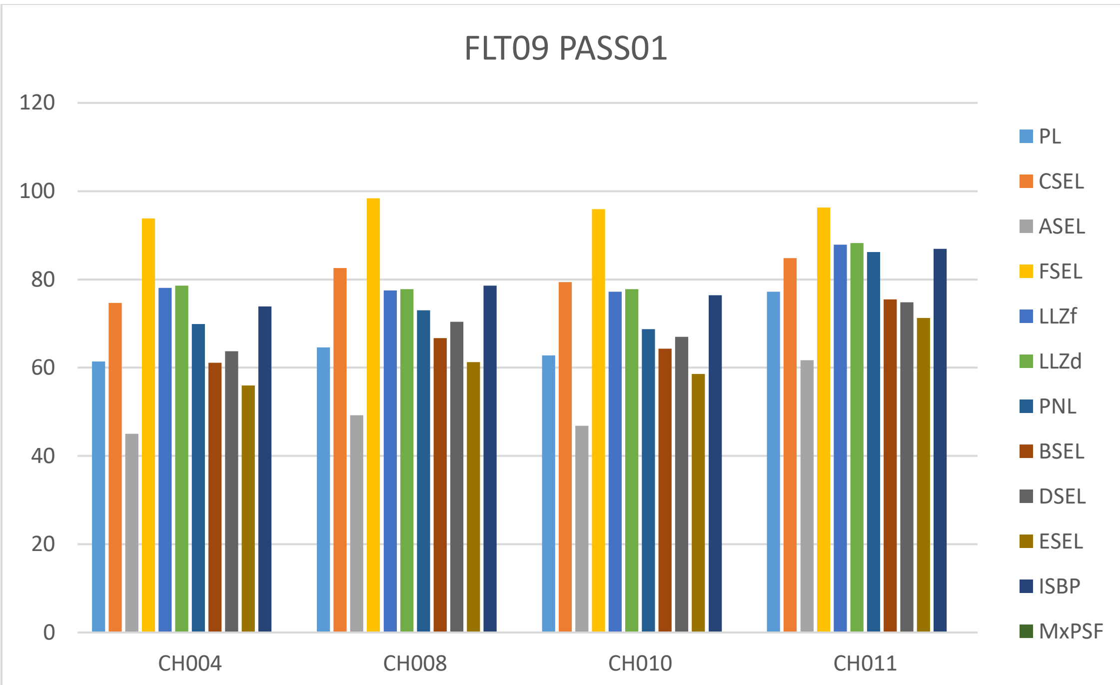
XVIII. Flight 08 Pass02 11-May-2017 17:24:02.954 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	MxPSF	
82.1	93.9	66.1	108	93.6	93.8	91.4	81.7	82.4	76.9	93.8	0.41	CH001
81.5	91.6	65.9	98.7	92.7	92.9	91.1	81.1	80.5	76.4	92.3	0.28	CH002
70.8	87.5	54.9	102.2	85.9	86.2	78.5	71.7	74.9	66.4	84.5	0.25	CH003
70.9	87.4	55	102.2	86.1	86.4	78.6	71.7	74.9	66.4	84.5	0.26	CH004
77.9	89.5	63	105.3	89.7	89.9	86.9	77.4	78.4	73.1	89	0.31	CH005
78.1	89.5	63.1	105.5	89.9	90.1	87.1	77.5	78.5	73.2	89.2	0.31	CH006
76.8	87.5	61.2	104.6	90.3	90.9	85.4	73.9	76.1	69.5	87.9	0.26	CH009
77.9	88.4	62	105.4	91.2	91.8	86.6	74.8	77.1	70.4	89	0.29	CH010
83.7	91.3	67.7	105.6	95.6	96	92.7	80.1	80.5	76.2	93.6	0.33	CH011
80	91.3	64.8	107.5	91.3	91.8	88.6	78.5	80.1	74.3	91.2	0.39	CH013
79.9	91.4	64.7	107.5	91.4	91.9	88.6	78.4	80.1	74.2	91.1	0.38	CH014



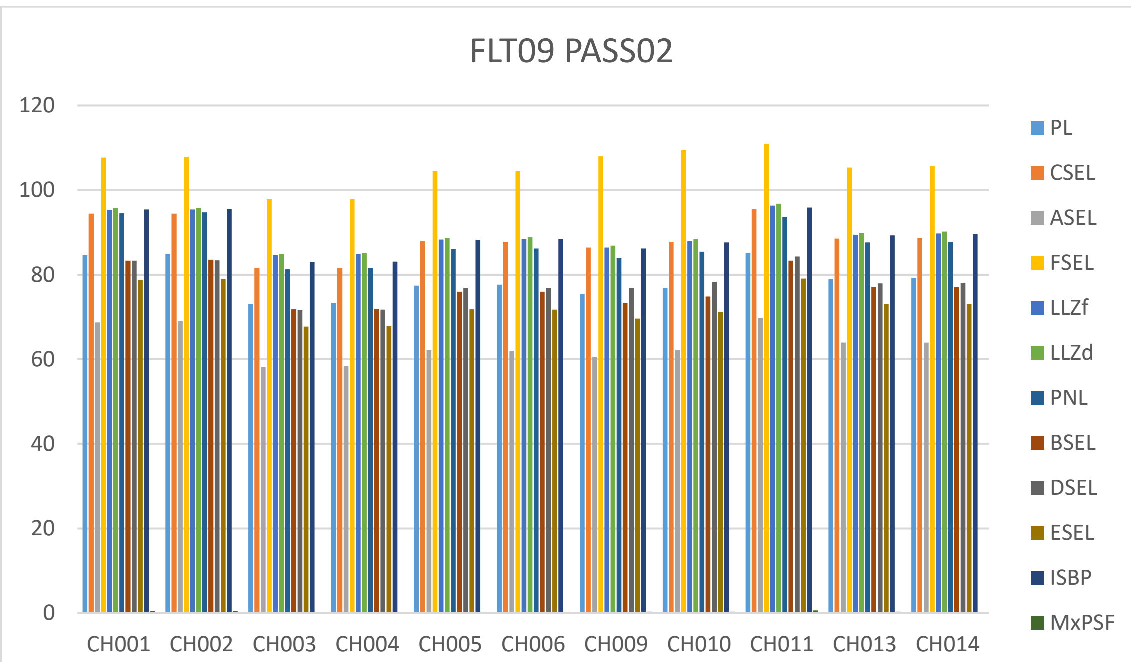
XIX. Flight 09 Pass01 11-May-2017 19:07:14.017 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	MxPSF	
61.4	74.7	45	93.8	78.1	78.6	69.9	61.1	63.7	56	73.9	0.08	CH004
64.6	82.6	49.2	98.4	77.5	77.8	73	66.7	70.4	61.3	78.6	0.14	CH008
62.8	79.4	46.8	95.9	77.2	77.8	68.7	64.3	67	58.6	76.4	0.09	CH010
77.2	84.8	61.7	96.3	87.9	88.2	86.2	75.5	74.8	71.3	86.9	0.15	CH011



XX. Flight 09 Pass02 11-May-2017 19:52:35.035 UTC

PL	CSEL	ASEL	FSEL	LLZf	LLZd	PNL	BSEL	DSEL	ESEL	ISBP	MxPSF	
84.6	94.4	68.7	107.7	95.3	95.7	94.5	83.3	83.3	78.7	95.4	0.46	CH001
84.9	94.4	69	107.8	95.4	95.8	94.7	83.5	83.4	78.9	95.6	0.46	CH002
75.4	86.4	60.5	108	86.4	86.9	83.9	73.3	76.9	69.6	86.2	0.28	CH009
76.9	87.8	62.2	109.4	87.9	88.4	85.4	74.8	78.3	71.2	87.6	0.31	CH010
78.9	88.5	63.9	105.3	89.4	89.9	87.6	77.1	77.9	73	89.3	0.27	CH013
79.2	88.7	63.9	105.6	89.7	90.2	87.8	77.1	78.1	73.1	89.6	0.26	CH014
77.4	87.9	62.1	104.5	88.3	88.6	86	76	76.9	71.8	88.2	0.25	CH005
77.6	87.8	62	104.5	88.4	88.8	86.2	76	76.8	71.7	88.4	0.25	CH006
85.1	95.5	69.8	110.9	96.3	96.8	93.7	83.3	84.3	79.1	95.9	0.62	CH011
73.1	81.6	58.2	97.8	84.6	84.8	81.3	71.8	71.6	67.7	82.9	0.13	CH003
73.3	81.6	58.3	97.8	84.8	85.1	81.6	71.9	71.7	67.8	83.1	0.13	CH004



D. Feedback Survey Comments

Respondent 44:

1) Text reminders probably would have been more useful if I had received early in the morning like at the 7 or 8am hours. I did not get the reminders until the afternoon (2:29 pm, 1:19 pm) so those days I had forgotten for the morning hours (except is ws in the control room for the 1:19 pm text). The one on Thurs was 6:56 am which was good.

2) A reminder at the end of the day to fill out the survey would not have annoyed me. I forgot 2 of the days. I probably would have put notes in the end of the ay survey to note how many booms my kids heard that day as they said one day some of them heard 3 or 1. They were where the SUBUDA was over on the base housing side.

3) I would recommend being careful on which email serve (or more importantly the addres) as at least one of the emails I received ended up in the ""spam"" holding area that I never look at.

4) I apologize for not reading more closely the original email that gave the link and instructions for using the link in the email to fill out the survy for the boom. When the text reminders had the link, that worked better/best. An email gets lost very easily that by Tuesday, something on Monday can be far down in the weeds and not easily retrievable.

5) One other recommendation as one area I focuson is providing information in an easily digestible format for the lowest common denominator. A little more formatting of the email helps immensely for those that 'scan' emails to quickly find the key points of info. Various methods are available for tat. Something maybe as using bullet list, bold/colored fonts to point out a user's ID, or even to use an HTML type of email that had a button that better registered their were links in the email of which one was for a pre-test survey and then another 'buton' link to the daily & per boom surveys. Food for thought.

6) My biggest takeaway for when I am trying to solicit help is to make it super easy, super user friendly, and provide options that work best fo"

Respondent 47:

Geolocation never worked for me. I did ensure my settings were as requested.

Respondent 49:

Selectable dates versus typing it in. No ability to go back if you make a mistake. Add instructions on how to make a short cut on iPhones and androids.

Respondent 196:

The geolocation was tough to tell if it was really the right spot. GPS was poor being inside and I could not manipulate the map to find features to check the location of the pin.

E. Text messages Summary

The text messages were sent via Google Voice using a desktop and/or laptop computer. Each subject was sent a text message individually for dates and time listed (time listed is Eastern Time; subjects were in the Pacific time zone).

Date: May 9

Time: 5:28pm

Message: Please remember to listen for the booms and fill out the daily summary

Date: May 9

Time: 7:45pm

Message: Please remember to listen for the booms and fill out the daily summary

Date: May 10

Time: 10:40am

Message: Remember to listen for the booms today. When you hear one, please access the survey at http://src.survey.psu.edu/NASA/

Date: May 10

Time: 3:49pm

Message: Please remember to listen for the booms and fill out the daily summary

Date: May 10

Time: 7:51pm

Message: Please remember to listen for the booms and fill out the daily summary

Date: May 11

Time: 9:57am

Message: Please remember to listen for the booms and fill out the daily summary http://src.survey.psu.edu/NASA/

Date: May 11

Time: 5:25PM

Message: Please remember to complete your response to each boom event and daily summary

surveys at: [http://src.survey.psu.edu/NASA/] as well as the background survey (the link was in your email sent on Monday). You will receive another link tomorrow via email for the final survey.

Date: May 12 (summary text after the 3 day flight)

Time: 9:05am

Message: The AFRC low boom test is complete and we would appreciate your feedback.

Please complete the post-test survey at: https://pennstate.qualtrics.com/jfe/form/SV_e2jBOclZNVrXVpr

If you have not yet completed the other surveys, please remember to complete your final daily summary survey at: [http://src.survey.psu.edu/NASA/] as well as the background survey using the link sent in the email on Monday.

F. References

Juliet Page et. al. March 2014 “Waveforms and Sonic Boom Perception and Response (WSPR): Low-Boom Community Response Program Pilot Test Design, Execution, and Analysis”

H. QSF18 OMB Application

The following pages provide Appendix H. This appendix file is provided separately from the main body of the report.

Support Statement for Information Collection Requirements

Waveforms Sonic Boom Perception and Response Risk Reduction (WSPRRR) Program

Form names and numbers:

OMB Control Number: -xxxx

OMB 83I states: A Supporting Statement, including the text of the notice to the public required by 5 CFR 1320.5(a)(i)(iv) and its actual or estimated date of publication in the Federal Register, must accompany each request for approval of a collection of information. The Supporting Statement must be prepared in the format described below, and must contain the information specified in Section A below. If an item is not applicable, provide a brief explanation. When Item 17 of the OMB Form 83-I is checked "Yes", Section B of the Supporting Statement must be completed. OMB reserves the right to require the submission of additional information with respect to any request for approval.

Part A. Justification

1. Need for the Information Collection: Explain the circumstances that make the collection of information necessary. Identify any legal or administrative requirements that necessitate the collection. Attach a copy of the appropriate section of each statute and regulation mandating or authorizing the collection of information.

Supersonic flight over land is currently restricted in the U.S. and many countries because sonic boom noise disturbs people on the ground and can potentially damage private property. NASA has developed a method for generating low level sonic boom noise similar to that anticipated for quiet supersonic flight. As sufficient research is assembled, there is potential for a change in federal and international policy.

The Waveforms Sonic Boom Perception and Response Risk Reduction (WSPRRR) test will utilize a specialized maneuver developed by NASA using an existing F-18 research aircraft to correlate human annoyance response with low level sonic boom noise in a community setting. This effort is designed to evaluate remote aircraft basing and operations, community engagement, sonic boom measurements, and community annoyance surveys. The effort will improve research methods for future community-scale response testing using a purpose-built, low boom flight demonstrator (LBFD).

NASA supported two prior risk reduction field tests to evaluate data collection methods for low boom community response at Edwards Air Force Base (EAFB) in November 2011(see ref. 1&2). The findings from both studies are not readily generalizable to a larger population, as the residents at EAFB are accustomed to hearing full level sonic booms on a routine basis.

2. Use of this Information: Indicate how, by whom, and for what purpose the information is to be used. Except for a new collection, indicate the actual use the agency has made of the information received from the current collection.

The outcomes from this F-18 low boom community noise test will provide guidance for the development of the future LBFD tests by developing methods for noise measurement, dose estimation techniques, and the validation of survey methods. The research will assess acceptability of low level sonic boom noise, with the premise that the variables influencing acceptability are stimulus factors, situational factors, and psychosocial factors. Analysis of the data gathered will provide understanding of the association of various noise metrics with the annoyance response. The findings will be published in technical reports that will be available to interested users, such as government officials, aircraft designers, and other researchers. The field test design is modeled after a similar community test conducted on annoyance response from blast military training noise (Pater, 2007) which was sponsored by the Strategic Environmental Research and Development Program under OMB Approval No. 0710-0015.

The low boom is a new noise source. Past sonic boom research evaluated full scale booms, with levels that were approximately 1 psf or greater. The low booms are anticipated to be much lower in level, approximately 0.2 to 0.6 psf.

Single event ratings and cumulative daily ratings are needed to compare to federal policy and other research assessments of aviation noise annoyance. Currently FAA quantifies aircraft noise exposure using the Day-Night Average Sound Level (DNL), which is a cumulative, 24-hour equivalent sound level based on annual aircraft operations. Both single event and daily cumulative noise levels and survey responses are being gathered, to provide a comprehensive dose response data set. The low boom noise from overland supersonic operations will affect a much larger percent of the population than the noise from the takeoff and landing operations at airports. The proposed effort is aimed at providing answers to the following questions:

- At what single event and/or cumulative daily level (threshold) of low boom noise does a community become annoyed?
- What percentage of people are annoyed at a given level of low boom noise?
- What percentage of booms go unnoticed for a given noise level?
- How much does annoyance change with a change (either an increase or decrease) in the number of low boom noise events for the same cumulative level?
- How are categorical attributes such as vibration, rattle and startle related to the annoyance response?

The survey includes automated geo-location to analyze the annoyance response data at the time of the boom to estimate the noise dose. The responses to the survey questions will provide data to assist in interpreting the results of the dose-response models.

3. Use of Information Technology: Describe whether, and to what extent, the collection of information involves the use of automated, electronic, mechanical, or other technological collection techniques or other forms of information technology, e.g., permitting electronic submission of responses, and the basis for the decision for adopting this means of collection. Also describe any consideration of using information technology to reduce burden.

Information Technology is implemented by using both smart phone and web- based surveys for the modes of response, text messages to prompt responses and the use of GPS to identify the respondents' location. The survey instruments will be mobile enabled web surveys programmed into The Pennsylvania State University Survey Research Center's (SRC) Qualtrics survey platform. Qualtrics is a mobile enabled web based survey software platform that provides the latitude and longitude position of a GPS-enabled device. The SRC has also implemented a prototype front-end mapping application that provides a visual map and allows the respondent to provide a location if the automated system is not accurate. All data collected using the mobile enabled web surveys will include time stamps and automated approximate geographic coordinates.

Prior low boom noise research (NASA/CR-2014-218180) compared paper, web and smart-phone based interviews to assess residents' annoyance response. The smart phone had a 45% response rate, paper had 58% and web had 50% for an aggregate response rate of 51% across all modes. The smart phone and web based response modes were chosen for this test because response rates were similar and they provide ease of access for the respondent and facilitate implementation. For WSPR, the daily summary survey response, paper, web and smart phone all exceeded 80 percent.

Participants will be asked to rate their perception of the low booms each time they notice a sonic boom event, and to provide a daily summary of their low boom perceptions. The respondent will provide consent to have location services enabled on their device and to allow their location to be retrieved and sent through the mobile survey.

The use of technology reduces participant response burden as they are afforded the opportunity to use their privately owned, readily available device. The technology also reduces burden to the research team as it provides an automated method to gather and tabulate data.

4. *Efforts to Identify Duplication: Describe efforts to identify duplication. Show specifically why any similar information already available cannot be used or modified for use for the purposes described in Item 2 above.*

The proposed research is the first flight test of this new noise source over a "non-acclimated" community to gather data to correlate human annoyance with low level sonic boom noise. Previous tests of low level booms have been conducted to evaluate data collection methods over an "acclimated" community of residents accustomed to hearing full booms. The acoustics literature on full booms and similar impulsive noises were studied extensively. Relevant references are provided at the end of SectionB.

5. *Burden on Small Business: If the collection of information impacts small businesses or other small entities (Item 5 of OMB Form 83-I), describe any methods used to minimize burden.*

Collection of this information does not have a significant impact on small businesses.

6. *Consequences of Not Collecting the Information: Describe the consequence to Federal program or policy activities if the collection is not conducted or is conducted less frequently, as well as any technical or legal obstacles to reducing burden.*

This information is not scheduled to be collected by any other agency or program. This information collection is a risk reduction measure to allow NASA to refine techniques to assess and predict human response to low boom noise. Non-collection of this data places additional risk on future dose-response tests with the LBFD.

7. *Special Circumstances: Explain any special circumstances that would cause an information collection to be conducted in a manner:*

Low booms are a new noise source. Previous full scale booms were approximately 1 psf or more, and sounded like fireworks. The low boom sounds more like distant thunder. It is anticipated that the flight design for the noise dose schedule will include 7 days of flights over a 10-day test period, allowing for days with no booms due to weather, flight circumstances or simply as 'rest' days. The number of booms per day will vary throughout the test, with a typical range of 0 to 6 booms per day, and a potential for 8 booms maximum per day.

8. *Consultation and Public Comments: If applicable, provide a copy and identify the date and page number of publication in the Federal Register of the agency's notice, required by 5 CFR 1320.8(d), soliciting comments on the information collection prior to submission to OMB. Summarize public comments received in response to that notice and describe actions taken by the agency in response to these comments. Specifically address comments received on cost and hour burden.*

The 60-day and 30-day Federal Register notice were published for comments. The 60-day Federal Register Notice xx-xxx was published on mm/dd/2017, FRN Vol xx, page xxxxx.

The 30-day Federal Register Notice was published on mm/dd/2017, FRN Vol xx, page xxxxx.

9. Payments to Respondents: Explain any decision to provide any payment or gift to respondents, other than remuneration of contractors or grantees.

The Baseline Survey Recruitment Mailing includes a printed survey, a cover letter, a business reply envelope and a $5 token incentive sent to all potential recruits. At the end of each week in which participants maintain full participation, they will be compensated $25. The total compensation per respondent who completes the surveys every day for two weeks is $55.

The use of a token is recommended in the Tailored Design Method (Dillman, Smyth and Christian, 2009) recruiting strategy which utilizing a targeted Address Based Sampling (ABS) approach. A small pre-incentive of $5 can increase response rates by 10 to 15%.

10. Assurance of Confidentiality: Describe any assurance of confidentiality provided to respondents and the basis for the assurance in statute, regulation, or agency policy.

The survey will conform to the practices as approved by the Institutional Review Board at The Pennsylvania State University and NASA Langley Research Center. Each survey respondent will be told that their responses are voluntary and their identities will not be associated with their responses. As such, their responses are treated as confidential. All individuals who participate, will be assigned a unique identification number that will be associated with their survey responses. The participants name, email, cell phone number and address will be used for test communications and determination of noise dose. The contact information will be destroyed within a reasonable period after the completion of the field test.

All subjective data sources will be merged into a single data set that will allow for detailed analysis. All personally identifiable information will be removed from the data and will only be linked by case ID

11. *Sensitive Questions: Provide additional justification for any questions of a sensitive nature, such as sexual behavior and attitudes, religious beliefs, and other matters that are commonly considered private. This justification should include the reasons why the agency considers the questions necessary, the specific uses to be made of the information, the explanation to be given to persons from whom the information is requested, and any steps to be taken to obtain their consent.*

There are no questions of a sensitive nature in any of the information collection protocols.

12. *Respondent Burden Hours and Labor Costs: Provide estimates of the hour burden of the collection of information.*

The following sections (A –E) are addressed in the Tables provided below.

A. ANNUAL BURDEN HOURS:

The maximum total burden across respondents over the 2 week test is 2000 hours, assuming 500 respondents and 4 hours per respondent. See supporting tables below.

B. NUMBER OF RESPONDENTS:

See discussion on sample size based on noise exposure in Part B.

C. RESPONSES PER RESPONDENT:

D. AVERAGE BURDEN PER RESPONSE:

E. FREQUENCY OF RESPONSES:

Total Cost Burden of Responses per Respondent					
Survey Instrument	Time per respondent (minutes)	Frequency of response (#/day)	Frequency of response over test (#days/test)	Total per respondent	Total across all 500 respondents, minutes (hours)
Background	15		1	15	7500 (125)
Single Event	2	10 (max)	10 (max)	200	100,000 (1666.66)
Daily Summary	2	1	10 (max)	20	10,000 (166.66)
Post Test	5		1	5	2,500 (41.67)
Total				240	120,000 (2,000)

Annualized Cost to Respondent			
Survey Instrument	Total across all 500 respondents, minutes (hours)	Hourly wage rate $7.25	Respondent Cost
Background	7500 (125)	$7.25	$906.25
Single Event	100,000 (1666.66)	$7.25	$12083.29
Daily Summary	10,000 (166.66)	$7.25	$1208.29
Post Test	2,500 (41.67)	$7.25	$302.11
Total	120,000 (2,000)	$7.25	$14500.00

13. *Estimates of Cost Burden to the Respondent for Collection of Information: Provide an estimate for the total annual cost burden to respondents or record keepers resulting from the collection of information. (Do not include the cost of any hour burden shown in Items 12 and 14).*

No additional cost burden will be imposed on respondents aside from the labor cost of the burden hours shown above.

14. *Cost to the Federal Government: Provide estimates of annualized costs to the Federal government.*

The annual costs of Federal employees for monitoring the contract are estimated to be $90,000, or 0.5 FTE. This estimate includes time spent by the Technical Monitor, as well as the contracting officer and other NASA employees who participate in technical interchange meetings and reviews.

The contractor team is currently funded at $1,593,634 total over a 3 year period for planning, executing and analysis of the data from the community tests.

NASA is concurrently supporting the flight team for this test. This includes daily ground and flight support for 3 F-18 flights per day over the course of a 2-week test. The NASA field team will be at the remote field location over a 3 week period. The estimated cost to NASA for this portion of the research support is $900,000 including aircraft flight costs (research and deployment), civil servant/NASA contractor labor and travel for about 19 days.

15. *Changes in Burden: Explain the reasons for any program changes or adjustments reported in Items 13 or 14 of the OMB Form 83-I.*

This is a new information collection. No change in the burden is anticipated.

16. *Publication of Results: For collections of information whose results will be published, outline plans for tabulation and publication. Address any complex analytical techniques that will be used. Provide the time schedule for the entire project, including beginning and ending dates of the collection of information, completion of report, publication dates, and other actions.*

A comprehensive report to NASA is planned upon completion of the research and will be published as a NASA Contractor Report (CR) freely available on the NASA Technical Reports Server. Findings will be published in peer-reviewed journals and may be presented at appropriate conferences and published in professional refereed journals.

17. If seeking approval to not display the expiration date for OMB approval of the information collection, explain the reasons that display would be inappropriate.

Not applicable. This research will display the expiration date for OMB approval of this information collection on the background survey/consent document.

18. Explain each exception to the certification statement identified in Item 19, "Certification for Paperwork Reduction Act Submissions," of OMB Form 83-I.

Not applicable. There are no exceptions to the certification statement.

B. Collections of Information Employing Statistical Methods

Noise metrics will be calculated for each single boom event and for daily cumulative noise exposure. The variables that influence the annoyance response are the noise stimulus factors, situational factors, and psychosocial factors.

The Steven's Mark VII calculation, PLdB, derives the perceived level of loudness (Stevens, 1972). It is a single number rating for outdoor sonic boom level that correlates with human assessment of loudness. The PLdB metric implemented here for sonic booms is an approximation of Steven's Mark VII Perceived Level and is calculated using a time constant of 70 msec (Shepherd and Sullivan, 1991).

<u>1. Potential respondent universe</u>

The PSU Survey Research Center is obtaining the potential sample using address based sample (ABS) from Survey Sampling International (SSI). Typically, Zip Codes are used to define a survey community, but smaller geographies can be used. The target population is residents exposed to low booms created by the F-18 dive maneuver, whether they are at home or away from home. The sampling frame consists of all residences within predicted sonic boom noise contours (Page and Downs, 2017) using PCBoom6 (Page *et al.,* 2010). Actual sonic boom levels will be obtained via acoustic measurements during the community response test. The target community will be divided into geometric grid cells under the boom footprint and census definitions (i.e., census tracts, block groups or blocks) may be used for greater geographic precision.

2. Procedures for the Collection of Information

➢ Statistical methodologies for stratification and sample selection

The research plan is to sample from the population utilizing a targeted ABS approach towards a goal of reaching 500 respondents to complete the pre-survey and participate in the single-event and End of Day/End of Night surveys. The recruiting strategy utilizes a Tailored Design Method (Dillman, Smyth and Christian, 2009) approach to reach 2000 homes in the targeted area. A complete enumeration of households will be conducted within the calculated boom footprint area across the community, from which a random sample of households will be selected for recruitment using Address Based Sampling. In areas with sufficient population density, a systematic random sample will be selected by determining a random starting point on the enumerated list of available households and using a sampling interval. The interval will be based on the ratio of required respondents to the total number of available households in that area. For each household recruited, we will ask for the person over 18 years of age with the most recent birthday to identify the resident that would participate. The contact interview ensures that respondents both live and work within the expected sonic boom footprint area.

➢ Sample size

To evaluate the sample size required, we mimic the analysis outlined in "Research Methods for Understanding Aircraft Noise Annoyances and Sleep Disturbance", released by the NAS in 2014. As such, data simulation of varying sample sizes evaluates the effect of the sample size on both precision of our estimation of important model parameters and, similarly, the power to detect significant model parameters, varying the significance of parameters under investigation. Informed guesses for the many required inputs to the simulation are obtained from the 2011 WSPR study (Page *et al*, 2012) and a recent 2018 study of AFRC personnel response to sonic booms conducted in 2017. Data from these events was utilized to assess:

- reasonable response rates for participants,
- reasonable values for quantities governing the dose-response relationship,
- reasonable annoyance response profiles.

A review of data from these two studies indicate that response rate can vary from ~7% to 45% on average. These studies differ from the planned community response test as follows:

- The participants were at home during WSPR 2011 or at work during the recent 2018 study of AFRC personnel. During the community response test the participants are expected to be freely mobile and busy with work/life events which may affect their response rate
- During WSPR 2011 and the recent 2018 AFRC study, all participants were residents or employees on Edwards Air Force Base that were familiar with sonic

booms and motivated to support each of the studies. One of the major objectives of the planned community response test is to engage a “non-acclimated” population in an area where sonic booms do not normally occur. We anticipate this population to provide a different response rate than what was observed during the previous studies.

- During WSPR 2011 and the recent 2018 AFRC study, the participants were exposed to some sonic booms which were louder than what is planned for the community response test. The community response test will employ sonic booms of the level anticipated to be delivered by the LBFD aircraft.

Given these differences several values were explored for average response rate in the range of what was observed during the previous studies. A conservative value of 7% was selected to ensure adequate capture of data to support statistical analysis of the current effort. This approach provides conservative estimates of statistical power and precision in the case that the response rates are higher. The WSPR 2011 effort presented boom levels comparable to the current proposed effort, and exhibited a slope of approximately 0.06 for the PL metric. Therefore, slopes from 0 (no relationship) to 0.03 are explored as a conservative estimate.

Using each sample size, and true value of the slope under investigation, we simulate 100 datasets as described above to assess whether a non-zero slope is detected and the degree of accuracy of the estimated slope (Figure 1). According to Figure 1b, there exists power to detect a relationship half as large as in WSPR 2011 (slope of .03 vs. .06) with a sample size of 300 (i.e. 300 total participants would detect this nearly 100% of the time, according to simulations). However, we expect far less annoyance due to low boom noise, and conservatively note that to achieve 80% power in detecting a relationship that is roughly 75% smaller (~.015), we need between 400-500 participants in total.

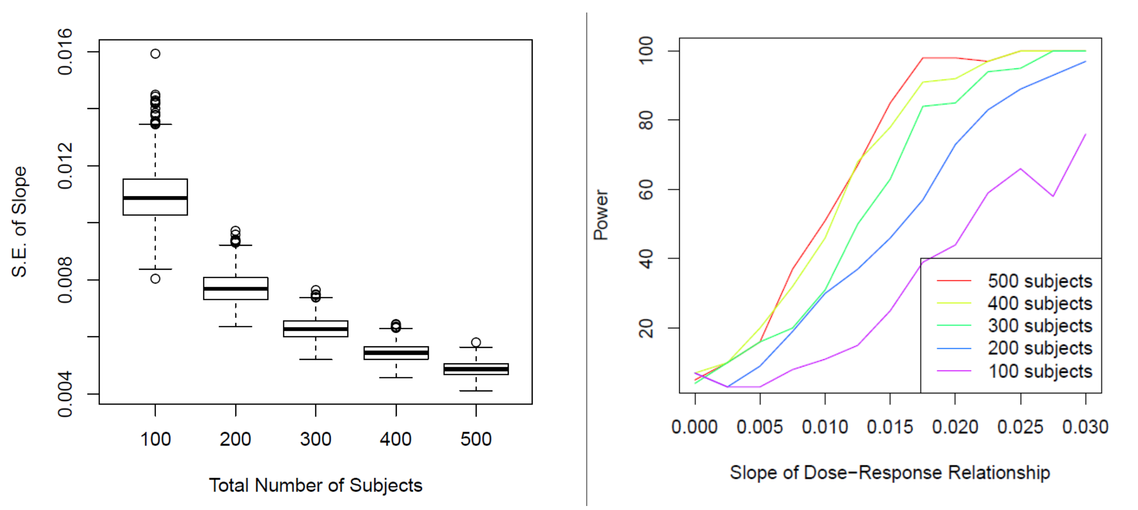


Figure 1a (Left): Precision for Slope with average 7% response rate. Figure 1b (Right): Power to Detect Various Slopes of Dose-Response Relationship as a Function of Sample Size for an average response rate of 7%

- Estimation Procedures and Analysis Model

The focus of the intended survey is annoyance response, thus single event annoyance will be rated after each boom event and a daily summary will provide a cumulative measure of annoyance.

The proposed research model is a multi-variable analysis model. Data will determine the components of the dose-response model of annoyance. The annoyance response is a function of non-noise co-variables, noise effects, and random effects, as outlined in the form: $Y = XB + B_M Met + ZA + E$, where:

Y is the *annoyance response* to be modeled, which is a function of:

Non-noise co-variables:
X is a matrix of covariates that interact with the annoyance response
B is a px1 vector of coefficients to be estimated

The non-noise co-variables include respondent factors such as demographics, attitudes, or household composition.

Noise effects:
B_M is a coefficient indicating the effect of the objective measure of noise
Met is a vector of the objective measures of noise

The noise effects include noise factors such as the noise level or number of booms in a day.

Random effects:
Z is a nxk matrix of random effects (e.g. respondent)
A is a kx1 vector of random variables
E is a nx1 vector of estimation errors

The random effects include individual variables such as health, or community wide effects such as stormy weather.

Y is the annoyance response (single events or daily summary) that is being modeled. The proposed analysis model is a random intercepts and/or random slopes model for the annoyance response and associated attributes. This can be treated as a generalized linear mixed model that could be fit in software such as the Statistical Analysis System (SAS).

- Degree of accuracy needed for the purpose described in the justification

As discussed in the sample size section above, the 2011 WSPR study would indicate that a maximum standard error for the slope of .06 would be acceptable. For our conservative order of magnitude reduction line of thinking, a maximum standard error for the slope of .0075 would be acceptable.

- Unusual problems requiring specialized sampling procedures, and

We are conducting a noise dose response test. The households included for sampling will be within the calculated boom footprint area across the community, rather than from the community at large.

- Any use of periodic (less frequent than annual) data collection cycles to reduce burden.

The community noise impact data that will be gathered is for a new noise source. It is anticipated that the flight design for the noise dose schedule will include 7 days of flights over a 10 day test period. See A7.

3. Maximization of Response Rates, Non-response, and Reliability

To maximize response rate, the survey instruments are accessible by web or smart phone to facilitate ease of access and to be more respondent-friendly.

The initial Background survey mailing includes an introductory letter that includes information on how to complete the survey on-line, a printed copy of the survey, a business reply envelope, and a token $5 incentive. Additionally, incentive compensation of $25 per week encourages continued participation throughout the two-week survey period.

Text messages will be used to encourage the completion of Background Survey, single-event surveys, and the Daily Summary Survey. A link to the survey will be embedded within the text messages.

4. Tests of Procedures or Methods

This noise research assesses community annoyance and response associated with low level sonic boom noise. Respondents' home and work addresses will be gathered at the time of their recruitment and noise levels will be measured by an array of distributed monitors throughout the community. These data are used to estimate respondents' single event exposure from noise levels measured at the closest noise monitor to their location. As we receive responses to single events, the time of response brackets the noise exposure for that individual event. For cumulative daily exposure, respondents will indicate whether they were at home or work for the morning, afternoon, and/or the entire day. These data, along with individual event geo-location data, allows for a determination of respondents' daily cumulative noise exposure.

These procedures and implementation methods for information collection will follow generally accepted social science research standards. A test of methods for was undertaken in the 2011 WSPR program (NASA/CR-2014-218180). An additional risk reduction assessment was conducted in May 2017 at NASA Armstrong Flight Research Center (APS Report 3494-420 REV, APS Report 3494-419-4-REV).

5. Statistical Consultation and Information Analysis

Standards and guidelines published by the International Commission on the Biological Effects of Noise (ICBEN) have been reviewed to develop survey questionnaire wording (Fields, 2001).

PSU Survey Research Center will gather and tabulate the data for analysis. Gaugler Consulting will conduct statistical analyses. In addition, our team contains several individuals with well-recognized expertise in noise and dose-response research who will contribute to the interpretation of the findings. The team includes researchers from APS, Eagle Aeronautics, Gulfstream Aerospace, Penn State University, Volpe National Transportation System Center, US DOT, KBR Wyle, and Gaugler Consulting.

PSU contact:
Kathleen Hodgdon
Applied Research Laboratory, The Pennsylvania State University
814-865-2447

Statistical Analysis:
Dr. Trent Gaugler
Gaugler and Associates
610-330-5328

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I. QSF18 IRB Documentation

The following pages provide Appendix I. This appendix file is provided separately from the main body of the report. Specifically, this appendix consists of the following documents.

- Hodgdon- Finalized IAA with NASA (PSU is B).pdf.
- IRB Approval letter WSPRRR QSF18 TGP 9 2018.pdf.
- I QSF18 1 Participant Recruitment Letter FINAL.pdf.
- I QSF18 2 reminder postcard.pdf.
- WSPRRR NASA IRB Rev 5 18.pdf.

PENNSTATE

IRB Authorization Agreement

The Pennsylvania State University

Name of Institution providing IRB review (Institution A):
NASA Langley Research Center Institutional Review Board
OHRP Federal-wide Assurance (FWA) Number:
NASA (FWA) acceptance code: FWA00019876 (Expires February 9, 2022)
IRB Registration Number:
IRB00009281
Name of Institution relying upon IRB review above (Institution B):
The Pennsylvania State University
OHRP Federal-wide Assurance (FWA) Number:
FWA00001534

The Officials signing below agree that Institution B may rely on the designated IRB for review and continuing oversight of its human participant research described below:

Name of Research Project:	~~Quiet Supersonic Flight Community Response~~ Waveforms Sonic Boom Perception and Response Risk Reduction (WSPRRR) Program
Institution A Principal Investigator(s):	Jonathan Rathsam
IRB Protocol Number:	PSU Study 10599
Sponsor or Funding Agency:	NASA
Award Number, if any:	Penn State ARL APS-15-07
Institution B Investigator:	Kathleen K. Hodgdon

The review performed by the designated IRB will meet the human participant protection requirements of Institution B's OHRP-approved FWA. The IRB at Institution A will follow written procedures for reporting its findings and actions to appropriate officials at Institution B. Relevant minutes of IRB meetings will be made available to Institution B upon request. Institution B remains responsible for ensuring compliance with the IRB's determinations and with the Terms of its OHRP-approved FWA. This document should be kept on file at both institutions and must be provided to OHRP upon request.

Signature of Signatory Official (Institution A): Date: 9/26/18

Print Full Name: Grant Watson Institutional Title: Dir Safety & Mission Assurance

Signature of Signatory Official (Institution B): Date: 9/27/18

Print Full Name: Candice A. Yekel

Institutional Title: Associate Vice President for Research, Director of Research Protections

PennState

Office for Research Protections
Vice President for Research
The Pennsylvania State University
205 The 330 Building
University Park, PA 16802

814-865-1775
Fax: 814-865-8699
orp@psu.edu
research.psu.edu/orp

COMMUNICATION PLAN

This form will be used to identify and document key communication roles for a study between the Reviewing IRB, Relying Institution(s), the Lead Study Team and the Relying Site Study Team(s).

Study Title:	Waveforms Sonic Boom Perception and Response Risk Reduction (WSPRRR) Program	
Study ID:	PSU: STUDY00010599	
Lead Study Team POC:	Name: Jonathan Rathsam	Contact Info: 757.864.9616; jonathan.rathsam@nasa.gov
Reviewing IRB POC:	Name: Thomas Popernack	Contact Info: 757.864.5163; thomas.g.popernack@nasa.gov
Relying IRB(s) POC:	Name: Philip Frum	Contact Info: 814.865.7986; plf13@psu.edu
Relying Site(s) Study Team POC:	Name: Kathleen Hodgdon	Contact Info: 814.865.2447; kkh2@psu.edu

Definitions

- **LEAD STUDY TEAM Point of Contact (POC):** Main person responsible for communication with the Reviewing IRB and facilitating communication between relying site study teams and the Reviewing IRB regarding the ceded study
- **RELYING SITE STUDY TEAM POC:** Main person responsible for communication with the Lead Study Team regarding the ceded study
- **REVIEWING IRB POC:** Main person responsible for addressing questions related to the Reviewing IRB's policies and procedures and review status for a ceded study
- **RELYING IRB POC:** Main person responsible for communication with the Reviewing IRB and local study team regarding the ceded study (e.g., personnel in the local IRB office or local human research protection program personnel)

Communication Plan

Communication Responsibility	Responsible Party	Notes
Conflict of Interest (COI): Providing applicable conflict of interest management plans for relying site study teams to the Reviewing IRB	☐ Reviewing IRB ☒ **Lead Study Team** ☐ Relying Site Study Team(s) ☐ Relying Site(s) POC(s) ☐ Other, specify:	

STUDY TEAM TRAINING & QUALIFICATIONS: Providing confirmation to the Reviewing IRB that relying site study teams have completed relevant training and are qualified to conduct the proposed research	☐ Reviewing IRB ☒ **Lead Study Team** ☐ Relying Site Study Team(s) ☐ Relying Site(s) POC(s) ☐ Other, specify:	
LOCAL CONTEXT INFORMATION: Providing local context information to the Reviewing IRB regarding state laws and institutional requirements that pertain to the review of the ceded study	☐ Reviewing IRB ☐ Lead Study Team ☐ Relying Site Study Team(s) ☐ Relying Site(s) POC(s) ☒ **Other, specify: Not applicable**	Data collection is occurring in one location – there are not different site locations.
IRB APPLICATION – STUDYWIDE: Preparing and submitting the studywide application for initial IRB review and studywide amendments to the Reviewing IRB	☐ Reviewing IRB ☒ **Lead Study Team** ☐ Relying Site Study Team(s) ☐ Relying Site(s) POC(s) ☐ Other, specify:	
IRB APPLICATION – SITE-SPECIFIC: Preparing and submitting the site-specific applications and site-specific amendments to the Reviewing IRB that address site variations in study conduct, informed consent language, HIPAA Privacy Rule requirements, subject identification and recruitment processes (including recruitment materials), and any other applicable components of the research	☐ Reviewing IRB ☐ Lead Study Team ☐ Relying Site Study Team(s) ☐ Relying Site(s) POC(s) ☒ **Other, specify: Not applicable**	Data collection is occurring in one location – there are not different site locations.
IRB DETERMINATIONS: Providing documentation of IRB determinations to relying site study teams	☐ Reviewing IRB ☒ **Lead Study Team** ☐ Relying Site Study Team(s) ☐ Relying Site(s) POC(s)	

	☐ Other, specify:	
IRB-APPROVED DOCUMENTS: Providing copies of IRB-approved materials to the lead study team	☒ **Reviewing IRB** ☐ Lead Study Team ☐ Relying Site Study Team(s) ☐ Relying Site(s) POC(s) ☐ Other, specify:	
IRB-APPROVED DOCUMENTS – RELYING SITES: Providing copies of the most current versions of IRB-approved materials to relying site study teams in a timely manner	☐ Reviewing IRB ☒ **Lead Study Team** ☐ Relying Site Study Team(s) ☐ Relying Site(s) POC(s) ☐ Other, specify:	
CONSENT FORM TEMPLATE: Providing the consent form template to relying site study teams	☐ Reviewing IRB ☐ Lead Study Team ☐ Relying Site Study Team(s) ☐ Relying Site(s) POC(s) ☒ **Other, specify: Not applicable**	Data collection is occurring in one location – researchers will use the same consent form. There are no site-specific consent forms.
CONSENT FORM LANGUAGE: Incorporating site-specific language into consent form(s) and providing these consent form(s) to the Reviewing IRB	☐ Reviewing IRB ☐ Lead Study Team ☐ Relying Site Study Team(s) ☐ Relying Site(s) POC(s) ☒ **Other, specify: Not applicable**	Data collection is occurring in one location – researchers will use the same consent form. There are no site-specific consent forms.
REVIEWING IRB POLICIES: Providing relevant Reviewing IRB policies to the relying study team	☐ Reviewing IRB ☒ **Lead Study Team** ☐ Relying Site Study Team(s) ☐ Relying Site(s) POC(s) ☐ Other, specify:	

CONTINUING REVIEW INFORMATION: Obtaining and collecting studywide information for continuing review to the Reviewing IRB	☐ Reviewing IRB ☒ **Lead Study Team** ☐ Relying Site Study Team(s) ☐ Relying Site(s) POC(s) ☐ Other, specify:	
CONTINUING REVIEW SUBMISSION: Submitting continuing review progress report to the Reviewing IRB	☐ Reviewing IRB ☒ **Lead Study Team** ☐ Relying Site Study Team(s) ☐ Relying Site(s) POC(s) ☐ Other, specify:	
REPORTABLE EVENTS: Reporting reportable events to the Reviewing IRB (e.g., unanticipated problems, noncompliance, subject complaints)	☐ Reviewing IRB ☒ **Lead Study Team** ☐ Relying Site Study Team(s) ☐ Relying Site(s) POC(s) ☐ Other, specify:	
CLOSURE REPORTS: Providing the Reviewing IRB with required information when a study is closed.	☐ Reviewing IRB ☒ **Lead Study Team** ☐ Relying Site Study Team(s) ☐ Relying Site(s) POC(s) ☐ Other, specify:	

Funded by the NIH Clinical and Translational Science Awards (CTSA) Program, grant number UL1TR001102-04S1 - www.smartirb.org

National Aeronautics and
Space Administration

Langley Research Center
100 NASA Road
Hampton, VA 23681-2199

August 31, 2018

Dr. Jonathan Rathsam
Structural Acoustics Branch
NASA Langley Research Center
2 North Dryden Street
B1208, R119
Hampton, VA 23681

Subject: Waveforms Sonic Boom Perception and Response Risk Reduction (WSPRRR) Program

Dr. Rathsam,

IRB members conducted a formal review of the subject study application and all accompanying documents. All actions from the review are submitted and approved. A copy of the NASA Armstrong AFSRB flight review approval will be submitted after the review later for our records. The submitted protocol is approved.

LaRC IRB approval is valid for a period of 1 year from the time of the initial review until August 31, 2019. Changes, including action item responses or modifications, do not extend the initial review and/or protocol renewal date. There is no grace period beyond one year from the last approval date. In order to avoid lapses in approval of your research and the possible suspension of subject enrollment, please submit your continuation request at least six (6) weeks before the protocol's expiration date. It is your responsibility to submit your research protocol for continuing review.

The Investigator must report any adverse reactions or unexpected problems resulting from this study to the LaRC IRB Chair.

NASA LaRC IRB MPA Code NASA3132281806HR
NASA LaRC IRB FWA 00020089

Thomas Popernack
Chairperson, Institutional Review Board
ARMD Projects (E1A)
MS 254, NASA Langley Research Center
thomas.g.popernack@nasa.gov

Dear (name):

NASA, where the first “A” stands for aeronautics, will be flying a supersonic jet offshore near Galveston this November as part of an aviation-related research program, and we are inviting you to join our test team. Seriously! The enclosed $2, which is yours to keep, no strings attached, is our way of thanking you just for reading this letter.

Here are the details: During the two-week period, our F/A-18 research jet pictured below will be flying faster than the speed of sound over the Gulf of Mexico and doing so in a way that residents of Galveston will hear what we call a “sonic thump.” This muffled sound is very different from the sonic booms you have heard about – or may actually have heard – in the past. In fact, you may not even hear the sonic thumps at all. And that’s where you can help NASA.

NASA F/A-18 Research Aircraft

If you volunteer, your job will be to go about your normal daily activities. When a sonic thump occurs, we want you to provide information about your location and your perception of the sound. You’ll do this by filling out a simple survey that you can access online with any computer or device you have handy. You’ll get the specific instructions after officially signing up, but we assure you filling out the survey is easy and will only take a minute or two each time you have something to report. There will be a maximum of 8 sonic thumps per day, all during the daytime.

In some cases, volunteers will be sent text messages reminding them to listen for the sound and be sure their phone or device's location settings are turned on. This will help us pinpoint with greater accuracy who is hearing what and where they are relative to a set of audio sensors that will be strategically placed around town in locations your local authorities have approved. So, if you volunteer and wonder why we need your phone number, that's why.

While the whole survey process is set up to be easy and take very little of your time, we also know we're asking for time out of your busy days. So if you choose to volunteer, in addition to our sincere thanks, you will be paid $25 per week for the two weeks of the survey, for a total of $50. If after the flights begin, you choose to stop participating – which you are free to do at any time -- your payment will be pro-rated for the time you actually helped us.

Most importantly, if you are interested in volunteering, we encourage you to sign up right away at the website below and tell us a little bit about yourself. Like any statistical survey, only a limited number of the entire population are selected to participate, and in our case, it's first come, first served. Once we have enough volunteers, the registration webpage will be closed. The website is run by Penn State University, who is helping NASA manage the survey. Your enrollment code can be found at the bottom of this letter. This code can only be used once.

Ethical review of this research study was provided by the NASA Institutional Review Board. If you have any questions regarding your rights as a research subject, how to volunteer or exactly what is expected of you, feel free to email the investigators at NASA-QSF18@mail.nasa.gov. If you would like to participate in the survey but do not have internet access, please contact NASA at (757) 864-9616.

To learn more about this research project and register as a volunteer participant, visit this website:

http://src.survey.psu.edu/NASA/

Enrollment Code:

(Front of Post Card. Post Card printed in Publisher.)

Penn State University
Survey Research Center
105 The 330 Building
University Park, PA 16802

Name

Address

City, State, Zip

(Back of Post Card.)

Dear (name)

A short while ago we mailed you a letter asking if you would volunteer for a NASA sponsored study about the sounds of supersonic flight. As a reminder, you will be compensated $50 for your participation in the two-week project ($25 per week you participate). If you have already responded, thank you! If you have not yet responded, you can still volunteer to participate. For more information and to enroll and complete the background survey, please visit:

http://src.survey.psu.edu/QSF18

Thank you for your willingness to participate in this research study!

NASA Langley Research Center
Institutional Review Board (IRB)
Application for Review of Human Subject Research

1. Title of Research Experiment

Waveforms Sonic Boom Perception and Response Risk Reduction (WSPRRR) Program

2. Investigators and Qualifications

2.1 Identify the organization.

Jonathan Rathsam
Structural Acoustics Branch, Research Directorate, NASA Langley Research Center

Kathleen Hodgdon
Penn State Applied Research Laboratory
WSPRRR team co-PI

2.2 List the PI(s), persons that will supervise the experiment and interact with test subjects, and other key personnel. Please provide contact information. (Name, e-mail address), their role in the experiment, and describe their qualifications and experience.

Jonathan Rathsam
(757) 864-9616
jonathan.rathsam@nasa.gov
M/S 463, NASA Langley Research Center
Hampton, VA 23681

Dr. Rathsam holds a Ph.D. in Engineering from the University of Nebraska. He has conducted human subject research tests at NASA Langley since 2010. He will serve as the Technical Monitor (CITI training completed)

Kathleen Hodgdon
kkh2@psu.edu
Penn State Applied Research Laboratory
ARL North Atherton Street
PO Box 30
State College PA 16804-0030

Kathleen Hodgdon is a Research Associate on the Penn State faculty with advanced degrees in Audiology and in Engineering in Acoustics. She has conducted laboratory and field studies on human perception since 1985. She is the PSU ARL IRB liaison. She serves as co-PI on the WSPRRR team, and is coordinating the subject related aspects of the WSPRRR research design.

Penn State Survey Research Center
330 Building (Suite 105)
The Pennsylvania State University
University Park, PA 16802
814-863-0170
Toll Free: 800-648-3617

Brian Sonak
bcs5@psu.edu
814-863-6210
PSU SRC Project Manager specializing in web surveys. Duties include project management, programming surveys, managing samples, and data coordination.

3. Other Reviews

3.1 List any other reviews of this proposed experiment (scientific reviews, institutional Review Board reviews, etc.) Note the associated recommendations, decisions, or conclusions from these reviews; or provide copies of minutes from the review.

The Office of Management and Budget is reviewing the design of this community survey and field test, in accordance with the Paperwork Reduction Act.

4. Abstract

4.1 Provide a brief abstract (500 words or less) of the proposed experiment.

Supersonic flight over land is currently restricted in the U.S. and many countries because sonic boom noise disturbs people on the ground and can potentially damage private property. NASA has developed a method for generating low level sonic boom noise similar to that anticipated for quiet supersonic flight. The Waveforms Sonic Boom Perception and

Response Risk Reduction (WSPRRR) test will utilize a specialized maneuver developed by NASA using an existing F-18 research aircraft to gather data to correlate human annoyance response with low level sonic boom noise in a community setting. The low boom noise from proposed overland supersonic operations will affect a much larger percent of the population than the noise from the takeoff and landing operations at airports.

This research is the first flight test for this new noise source over a “non-acclimated” community to gather data to correlate human annoyance with low level sonic boom noise. Past sonic boom research evaluated full scale booms, with levels that were approximately 1 psf or greater, in communities accustomed to hearing sonic booms. The low booms are anticipated to be much lower in level, approximately 0.2 to 0.6 psf. This research effort is designed to evaluate remote aircraft basing and operations, community engagement, sonic boom measurements, and community annoyance surveys. Measurements of the single event and estimates of daily cumulative noise levels and associated survey responses are being gathered to provide a comprehensive dose response data set. The findings of this effort will improve research methods for future community-scale response testing using a purpose-built, low boom flight demonstrator (LBFD).

5. Purpose and Benefits

5.1 Describe the objective of this experiment.

This research is the first flight test for this new noise source over a “non-acclimated” community to gather data to correlate human annoyance with low level sonic boom noise. The proposed effort is aimed at providing answers to the following questions:

• At what single event and/or cumulative daily level (threshold) of low boom noise does a community become annoyed?
• What percentage of people are annoyed at a given level of low boom noise?
• What percentage of booms go unnoticed for a given noise level?
• How much does annoyance change with a change (either an increase or decrease) in the number of low boom noise events for the same cumulative level?
• How are categorical attributes such as vibration, rattle and startle related to the annoyance response?

The responses to the survey questions will provide data to assist in interpreting the results of the dose-response models. As sufficient research is assembled, there is potential for a change in federal and international policy.

5.2 Describe the potential benefits that may accrue to individual test subjects. Describe the potential specific benefits to others. Identify the groups or segments of society that may benefit.

The individual participant will have the satisfaction of contributing to scientific research and will be compensated a maximum of $52 for their time. The Baseline Survey recruitment includes a $2 token incentive. At the end of each week in which participants maintain full participation, they will be compensated $25. The total compensation per respondent who completes the surveys every day for two weeks is $52.

The outcomes from this F-18 low boom community noise test will provide guidance for the development of the future LBFD tests by developing methods for noise measurement, dose estimation techniques, and the validation of survey methods. Analysis of the data gathered will provide understanding of the association of various noise metrics with the annoyance response. The findings will be published in technical reports that will be available to interested users, such as government officials, aircraft designers, and other researchers.

6. Test Subjects

6.1 What population will test subjects be drawn from (general public, pilots, NASA employees, contractor personnel, other)?

The participants will be drawn from the general public utilizing a targeted address based sample approach towards a goal of reaching 400 to 500 respondents is consistent with the OMB application.

This sample size was based on analysis using the findings from a prior low boom test NASA conducted at AFRC in 2011. The WSPR 2011 effort presented boom levels comparable to the current proposed effort, and exhibited a slope of approximately 0.06 for the PL metric. Therefore, slopes from 0 (no relationship) to 0.03 are explored as a conservative estimate. Using each sample size, and true value of the slope under investigation, we simulated 100 datasets to assess whether a non-zero slope is detected and the degree of accuracy of the estimated slope. The assessment showed that there exists power to detect a relationship half as large as in WSPR 2011 (slope of .03 vs. .06) with a sample size of 300 (i.e. 300 total participants would detect this nearly 100% of the time, according to simulations). However, we expect far less annoyance due to low boom noise, and conservatively note that to achieve 80% power in detecting a relationship that is roughly 75% smaller than that observed in WSPR 2011 (~.015), we need between 400-500 participants in total.

6.2 Describe the rationale for using the proposed participant population.

Recruiting respondents from the general public affords the best potential for a non-biased assessment of the human annoyance response to low level sonic boom noise in a community setting. The target population is residents exposed to low booms created by the F-18 dive maneuver, whether they are at home or away from home.

6.3 Are the test subjects covered by existing Center contract providing for worker's compensation or other injury insurance? ☐ Yes ☒ No

If NO, documentation of workman's compensation must be provided.

Workman's compensation not applicable. Participants are listening and responding in their own homes and workplaces.

6.4 Describe how the test subjects will be recruited. Supply a copy of sign-up sheets, newspaper advertisements, announcements, etc.

A complete list of households within the survey area will be compiled by Survey Sampling International. From this list, a systematic random sample of 4000 to 8000 homes will be selected using a random starting point and a sampling interval in order to reach the target sample size of 400 to 500 respondents. The recruiting strategy is a modified version of the Tailored Design Method (Dillman, Smyth and Christian, 2009), including multiple contact attempts and simple questions to maximize survey participation. Any member of the household that is qualified can enroll into the study by submitting a background survey.

6.5 Will the study utilize any pre-test or post-test screening (questionnaires or medical exams) of test subjects to determine their appropriateness for inclusion in the study or to protect their health and safety? ☒ Yes ☐ No

If YES, describe the screening process, the screening criteria, and its rationale. Attach a copy of any screening questionnaires or the description of any medical exams.

The initial screening process is provided at the beginning of the background survey. It will ensure that respondents are interested in participating in the study, are over 18, and ask for their name, contact information, home and work address to ensure that they both live and work within the expected sonic boom footprint area.

6.6 Does this experiment use test subjects whose ability to give informed and/or voluntary consent may be in question? ☐ Yes ☒ No

If Yes, describe the issue and explain in detail the procedures to be employed to ensure their protection.

6.7 Provide the duration of each test subject's participation in the experiment.

We estimate a maximum of 4 hours total (240 minutes) over a 2 week period of participation based on the following times:

Background survey including screening questions: 15 minutes

Single event survey after each boom (up to 10 max per day over 10 max potential flight days) 2 minutes each = 200 minutes total

Daily summary completed at the end of each of up to a max of 10 flight days taking 2 minutes each = 20 minutes total

Post test survey after test is completed 5 minutes

6.8 Provide the amount and type of compensation associated that will be provided to test subjects (payment, stipend, travel expenses, other). Is it from: ☐ TEAMS2 Contract ☒ Other Specify:

Compensation will be provided by the Penn State Survey Research Center. The Baseline Survey recruitment includes a $2 token incentive. At the end of each week in which participants maintain full participation, they will be compensated $25. The total compensation per respondent who completes the surveys every day for two weeks is $52.

6.9 Are there any consequences associated with not participating in the experiment or failing to complete the agreed upon activities? ☒ Yes ☐ No

If YES, describe consequences below:

Participation is voluntary and the participant may quit at any time. The payment may be pro-rated based on the duration of participation. Weekly payment is contingent on the participant providing survey responses during that week.

7. Description of Experiment

7.1 Schedule

List the expected start and completion dates for the experiment.

Flights are anticipated to be flown starting the week of November 5, 2018 for up to a maximum of 10 flight days. Potential flights will occur between 11/05/18 and 11/17/18.

7.2 Collaboration

Is this experiment being conducted in association or collaboration with any other department, agency, or organization (public or private)? ☒ Yes ☐ No ☐ N/A

If YES, identify the organizations and describe the collaboration and plans for sharing data.

Only PSU Survey Research Center researchers will have direct access to the participants' personally identifiable information and associated survey responses. All individuals who participate, will be assigned a unique identification number that will be associated with their survey responses. The participant's name, email, cell phone number and address will be used for test communications however it will not appear in the single event, daily summary or final feedback surveys. The participants will enter their unique code on project pages that correspond to their unique responses. This provides an extra layer of confidentially. The addresses provided will be used for determination of the noise dose. The contact information will be destroyed within a reasonable period after the completion of the field test. All personally identifiable information will be removed from the data and will only be linked by the unique ID. All subjective data sources will be merged into a single data set that will allow for detailed analysis.

The full contractor team will have access to de-identified noise dose and response data. This NASA sponsored team is led by Applied Physical Sciences (APS) and includes researchers from APS, Eagle Aeronautics, Gulfstream Aerospace, Penn State University, Volpe National Transportation System Center (US DOT), KBR Wyle, and Gaugler Consulting.

7.3 Information Privacy

Describe the information that will be collected about each test subject and how private information will be protected.

Only PSU Survey Research Center researchers will have direct access to the participants personally identifiable information and associated survey responses. All individuals who participate, will be assigned a unique identification number that will be associated with their survey responses. The participants name, email, cell phone number and address will be used for test communications and determination of noise dose. The contact information will be destroyed within a reasonable period after the completion of the field test. All personally identifiable information will be removed from the data and will only be linked by case ID. All subjective data sources will be merged into a single data set that will allow for detailed analysis. The full contractor team will have access to de-identified noise dose and response data.

7.4 Experiment Protocol

7.4.1 Describe the experimental procedures that will be followed. Submit copies of research protocols, questionnaires that test subjects are required to completed; plus copies of any instructions and debriefing information.

Participants will be asked to complete a background survey that includes the initial screening questions. They will also be asked to rate their perception of the low booms on a single event survey each time they notice a sonic boom event, and to provide a daily summary of their low boom perceptions. The respondent will provide consent to have location services enabled on their device and to allow their location to be retrieved and sent through the mobile survey. They will also complete a post-test survey to provide feedback.

The survey instruments will be mobile enabled web surveys programmed into The Pennsylvania State University Survey Research Center's (SRC) Qualtrics survey platform. Qualtrics is a mobile enabled web based survey software platform that provides the latitude and longitude position of a GPS-enabled device. The SRC has also implemented a prototype front-end mapping application that provides a visual map and allows the respondent to provide a location if the automated system is not accurate. All data collected using the mobile enabled web surveys will include time stamps and automated approximate geographic coordinates. Participants will be asked to provide their address if the geo-location feature is not enabled.

7.4.2 Will deliberate deception of test subjects be involved as part of this experiment? ☐ Yes ☒ No

If YES, explain the nature of the deception, why it is necessary, any possible risks that may result from the deception, and the nature of the debriefing with specific reference to the deception.

7.4.3 Will there be any deviation from the practice of complete disclosure and explanation of the experimental procedures during the debriefing? ☐ Yes ☒ No

If YES, explain the justification for the exception.

7.5 Equipment and Facilities

Identify any facilities and equipment used in this research that have been previously approved by the LaRC IRB.

7.5.1 Facilities

☐ Generic Flight Deck (GFD)
☐ Integration Flight Deck (IFD)
☐ Cockpit Motion Facility, Research Flight Deck (RFD)
☐ Development and Test Simulator (DTS)
☐ Air Traffic Operations Laboratory (ATOL)
☐ Human and Autonomous Vehicle Systems (HAVS) Laboratory
☐ Operator Characterization and Performance Investigations (OCAP) Laboratory

- [ ] Visual Imaging Simulator for Transport Aircraft Systems (VISTAS)
- [ ] Small Anechoic Chamber
- [ ] Aircraft Interior Acoustic Simulator
- [ ] Exterior Effects Room
- [ ] Sonic Boom Simulator
- [ ] Interior Effects Room
- [ ] NASA Ames ATC Lab
- [ ] NASA Ames AOL Lab
- [ ] FAA Technical Center research facilities
- [ ] FAA Flight Ops Simulation Lab (FOSL), Oklahoma City
- [ ] University of Iowa Operator Performance Lab (OPL)
- [x] Other:

If other, describe the equipment.

Use of NASA pilots to conduct F-18 flights over the community.

7.5.2 Equipment

- [ ] Reduced Oxygen Breathing Device (ROBD)
- [ ] Motion-base for GFD, RFD or IFD
- [ ] Oculometer or eye-trackers
- [ ] Performance and Behavioral Measures
- [ ] Electroencephalogram / Event-Related Potentials
- [ ] Electrocardiogram
- [ ] Electrodermal Activity
- [ ] Galvanic Skin Response
- [ ] Blood pulse, skin temperature
- [x] Electronic or paper surveys
- [x] Other:

If other, describe the equipment.

Geo-location enabled on participant's personal device for survey response.

8. Hazard Analysis and Safety Procedures

8.1 Describe and assess any test conditions that may pose a risk or any potential risks, physical, psychological, social or economic) and assess the likelihood and seriousness of such risks associated with the experimental procedures. If methods of research create potential risks, describe any other alternatives considered, and why they will not be used.

Participation in the surveys does not pose a risk to participants. Every effort will be made to ensure the confidentiality of your identity and the data that you provide. Each respondent will be provided with a unique link which will be associated with an access code (or "ID code"). Once the participant hits the enrollment button, they enter Qualtrics, a web enabled survey platform that is https. The respondent enters responses through the https Qualtrics survey platform. There will be no identifiable information in any dataset provided for analysis.

The noise source during the field test will be a NASA F-18 flying offshore. The F-18 flights are necessary to provide a realistic noise source over the entire community. While NASA research pilots are highly trained, there is a very small risk of damage or injury if an emergency occurs with the pilot or aircraft.

8.2 Are there any pre-existing medical or mental health conditions that may pose an increased risk to the test subjects while participating in the proposed research? ☐ Yes ☒ No
If YES, describe below.

8.3 Describe the safety features, equipment, practices, and procedures that will be used to mitigate hazards and protect test subjects during this experiment.

First responders and community leaders will be notified of the flight test days so that they are sufficiently informed to address community concerns. In the event that participating or non-participating community members become alarmed and report the boom noise, they will be provided information about the research test.

8.4 Describe any procedures that will be used to monitor and safeguard the health of test subjects. Identify any medical care that will be available or present on-site during the tests. If a physician will be on call during the test, note where the physician will be located. Describe any medical examinations that will be performed before the test, during the test, or after the test.

No monitoring of respondents' health is included in the design.

8.5 Describe any procedures that will be used for dealing with emergencies.

No emergencies are anticipated for the respondents.

9. Inconveniences or Discomforts

9.1 Does age, gender, and/or race serve as an independent variable in the proposed research? ☐ Yes ☒ No

If YES, please describe the rationale associated with inclusion of this/these independent variable(s), and describe the plan to ensure an equitable selection of subjects with reference to that independent variable.

10. Ethical Issues

10.1 Does the research involve financial relationships that could create potential or actual conflicts of interest? ☐ Yes ☒ No

If YES, identify any financial interest that the PI or other investigators have in the research study. Include any benefits that these individuals will derive from knowledge or products being developed by the study.

11. Informed Consent

11.1 Describe the procedure that will be used for obtaining informed consent. Supply a copy of the Informed Consent Statement plus any associated briefing or handout material.

The survey implementation will conform to approved Institutional Review Board practices. Each survey respondent will be told that their responses are voluntary and their identities will not be associated with their responses. As such, their responses are treated as confidential.

12. Expedited Review

12.1 Is the PU requesting an Expedited Review of the application based on the criteria listed in Appendix C of NPR7100.1? The activity described therein that is most applicable to research typically done at NASA Langley is "research on individual or group...in which the PI does not manipulate the subject's behavior and the research does not involve stress to the subjects".

If YES, other criteria, describe:

☐ Yes, Criteria described above ☐ Yes, other Criteria described below ☒ No

12.2 Are there similar experiments previously approved by the LaRC IRB? ☒ Yes ☐ No

If YES, please identify the experiments and the dates they were previously approved by the IRB and describe any changes/ differences.

A test of methods for was undertaken in the 2011 WSPR program (NASA/CR-2014-218180) under Penn State IRB 36961 with NASA review and approval. An additional risk reduction assessment was conducted in May 2017 at NASA Armstrong Flight Research Center (APS Report 3494-420 REV, APS Report 3494-419-4-REV) under Penn State IRB 6551 with NASA review and approval.

13. List any documents that accompany this application.

☒ CITI training certification

☒ Copy of advertisements or announcements to recruit subjects

☒ Informed Consent Statement

☐ Privacy Act Notice

☒ Questionnaires or surveys to be used

☐ Documentation from subject's company of their insurance coverage during the experiment (only if not using TEAM 2 contract)

☐ Other

If Other, describe the attachment.

J. QSF18 Survey Instruments Outline

The following pages provide Appendix J. This appendix file is provided separately from the main body of the report.

QSF18 Survey Instruments Outline

http://src.survey.psu.edu/qsf18/

Introductory Page

[seen when participants enter the URL from recruitment letter]

You are invited to participate in a NASA sponsored research survey about the sounds of supersonic flight. You must be at least 18 years of age to participate. To register as a participant, click the button "Click to begin"

To read about the study on nasa.gov, go to:
Quiet Supersonic Flight Community Response

The survey is being conducted by the Penn State Survey Research Center

This information collection meets the requirements of 44 U.S.C § 3507 as amended by section 2 of the Paperwork Reduction Act of 1995. The OMB control number for this collection is 2700-0167, which expires on 8/31/2021. We estimate that it will take 15 minutes to read the instructions and answer the questions. Send any comments relating to our time estimate to NASA-QSF18@mail.nasa.gov.

QSF18 Implied Consent and Background Survey

Smart phone/web based implementation

Thank you for volunteering to participate in this NASA research study to gather opinions about the perception of sonic thumps. There will be a maximum of 500 participants. We appreciate your participation, which is voluntary and confidential. You will receive compensation of $25 per week for the two weeks of the survey for a total amount of $50 as an expression of appreciation. If the survey is terminated before the end of the first week, participants who completed the survey until its termination will receive $25. If the survey is terminated after the first week, but before the end of the second week, participants who completed the survey until its termination will receive $50. If there is a question you do not want to answer, you may skip that question and move on to the next question. Your responses will be associated with your participant number and summarized so that the answers you provide cannot be associated with you or your household. You must be 18 years of age or older to consent to participate in this research. ***Responding to the survey questions implies your consent to participate in this background survey, and in the upcoming two week research study.***

During the research study you will go about your normal activities, and there will be supersonic flights in your area. The flights will produce audible sounds called sonic thumps. This muffled sound is very different from the sonic booms you have heard about – or may actually have heard – in the past. In fact, you may not even hear the sonic thumps at all. When a sonic thump occurs, you will be asked to provide information about your location and your perception of the sound. There are no foreseeable risks or discomforts associated with participating in this research.

You will be randomly assigned into one of two groups, one that receives reminders to listen for sonic thumps, and one that does not. The “no reminder” participants will simply respond when they hear a sonic thump. If you are in the reminder group, you will be sent reminders throughout the day. The message will read: “Did you just hear a sonic thump? Please click on the survey link, indicate your location, and answer yes or no. Please complete the survey questions”. This message will sometimes, but not always, be sent after a sonic thump and sometimes just as a reminder to listen. For all participants, please provide your responses as soon as possible after hearing each sonic thump. If you are driving when the sonic thump occurs, please wait until you have stopped driving. You will also be asked to complete a short daily survey at the end of each day, providing a rating of your perception of the sounds overall during that particular day. At the end of the research study we will provide the opportunity for your feedback on the surveys.

Participants have the option to use their own smart phones or other mobile devices to respond using the Qualtrics app, a mobile survey tool. Alternatively, you may choose to complete the surveys on the web. If you use your mobile device, we ask that you have location services activated on the mobile device you use to complete the survey. Your response location is required so that we can associate your location with the sound measured at the nearest noise monitor. You will need either Wi-Fi or Cellular connection access in order for your device to respond. ***Please ensure that location services are turned on when you respond to the surveys.***

To turn on location services for iPhone:

1. Go to Location in your iPhone's Settings by tapping: Settings > Privacy > Location Services.
2. Agree to allow location access always or while using the Survey application.

To turn on location services for Android:

1. Go to Location in Settings by Tapping Settings > Personal>Location.
2. Agree to allow location access always or while using the Survey application.

Every effort will be made to ensure the confidentiality of your identity and the data that you provide. The data will be password protected, so only researchers associated with this study will have access. Your participation is voluntary, so you may stop at any time, but your payment will be pro-rated for the time of participation. Please notify the researchers if you decide to withdraw from the study. Ethical review of this research study was provided by the NASA Institutional Review Board. If you have any questions regarding your rights as a research subject, how to volunteer or exactly what is expected of you, feel free to email the investigators at NASA-QSF18@mail.nasa.gov. If you have technical difficulties with the survey applications please contact the Penn State Survey Research Center at 1-800-648-3617.

Privacy Act Statement

Authority: National Aeronautics and Space Act (51 U.S. Code Ch. 201)
Purpose: The information will be used to summarize opinions about the perception of sonic thumps.
Routine Uses: The information provided will be anonymized and analyzed by researchers at Penn State and at NASA.
Disclosure: Furnishing this information is voluntary, although it is necessary to participate in the survey.

Eligibility to Participate

A1 Are you willing to participate in this study?
Yes. Go to A2.
No. Thank you for your interest in this research. Unfortunately, you do not meet the qualifications to participate.

A2 Had you heard about this test before you received our invitation to participate?
Yes. If yes, go to A2a.
No. If no, go to A3.

A2a How did you hear about it? Check all that apply.
Friend or family
Social media
Newspaper
On-line publication
TV or radio
Other [Text box for open ended address response]

A3 Are you 18 years of age or older?
Yes Go to A4.
No. Thank you for your interest in this research. You must be 18 years of age to participate.

A4 Are both your home and work addresses within the area of Hitchcock, Port Bolivar, Texas City, Tiki Island or Galveston [other location as warranted]?
Yes
No. Thank you for your interest in this research. Unfortunately, you do not meet the qualifications to participate.

Background Survey

A5 Please provide your name.

A6 Please provide the street address and/or building where you are during most of the work day.

A7 Please provide your home address

A8 Please provide your cell phone number. Providing this information implies your consent for us to contact you by cell phone/text message.

1. Cell phone number:

A9 Please provide your email address. Providing this information implies your consent for us to contact you by email. An email address is required to be part of this study. We recommend you do not use your work email address to avoid messages being blocked by filters on your work email servers.

1. Email address:

2. Can you receive text messages throughout the day?
   a. Yes
   b. No

Social and Demographic Characteristics

B1 What is your gender?
Male
Female

B2 In what year were you born? [Enter 4-digit year]

B3 Including yourself, how many people live in your household?

______ Number

B4 [IF B3 > 1] Do any children under age 6 live in your household?

1 Yes
2 No

B5 [IF B3 > 1] Including yourself, how many adults age 18 or older live in your household?

______ Number

B6 What is the highest grade or year of schooling that you completed? (Select one)

1 Grades 1 to 11
2 12th Grade No Diploma
3 High School Graduate or Equivalent (GED)
4 Some college, technical school, or 2-year degree
5 Bachelor's Degree (BA, AB, BS)
6 Some graduate work (no degree)
7 Masters, Doctoral, or Professional degree

Self Assessment of Hearing Ability

B7 Do you believe that your hearing is normal? How would you characterize your hearing ability?

1 Normal (Go to B9)
2 Somewhat diminished (Go to B8)
3 Severely diminished (Go to B8)

B8 [If B7>1] Do you have and wear a hearing aid, or hearing aids?

1 I wear a single hearing aid

2 I wear two hearing aids
3 I have hearing aids that I don't wear
4 I don't have and don't wear hearing aids

House Construction and Home Noise Environment

B9 Which of the following best describes the type of *home* in which you live?

1 Single-family detached (no common walls)
2 Duplex or single-family attached (at least one common wall)
3 Apartment building/condominium or dormitory
4 Other [SPECIFY] [text box]

B10 Which of the following best describes the construction type of the building in which you *work*?

1 Single residence type
2 Warehouse or flat box store
3 Single level office/school/commercial
4 Multi-floored office/school/commercial (2-3 floors)
5 Mid-rise multi-story (4 -11 floors)
6 High-rise multi-story (12 – 39 floors)
7 Skyscraper multi-story (40+ floors)

B11 How quiet or loud do you expect it to be in your home?

1 Very quiet
2 somewhat quiet
3 neither quiet nor loud
4 somewhat loud
5 very loud

B12 The research team may need to put noise monitoring equipment in residents' yards for the duration of the test. Would you be willing to have noise monitoring equipment located outdoors on your property?
[SELECT ONE]

1 Yes
2 No
3 Depends (Please contact us with questions or for additional information)

Attitudes and Experience with Neighborhood Noises

C1 We're interested in the noises that people hear in their neighborhood. Do you think your neighborhood is quiet or noisy or about average? Please select one.

1 Quiet
2 Noisy
3 Average

C2 For each statement, please indicate if you strongly disagree, moderately disagree, neither agree nor disagree, moderately agree or strongly agree.

a. I believe that people have a hard time getting used to noise.
   1 Strongly disagree
   2 Moderately disagree
   3 Neither agree nor disagree
   4 Moderately agree
   5 Strongly agree

b. I believe that with time most people adapt to noise.
   1 Strongly disagree
   2 Moderately disagree
   3 Neither agree nor disagree
   4 Moderately agree
   5 Strongly agree

c. I believe that with time I can adapt to noise.
   1 Strongly disagree
   2 Moderately disagree
   3 Neither agree nor disagree
   4 Moderately agree
   5 Strongly agree

d. I believe that with time I can get used to even the loudest noise.
   1 Strongly disagree
   2 Moderately disagree
   3 Neither agree nor disagree
   4 Moderately agree
   5 Strongly agree

C3. Next is a list of noises that might occur in your neighborhood. Please indicate how much each noise bothers, disturbs or annoys you. When you are at home, how much does noise from the indicated noise source bother, disturb, or annoy you?

a. Barking Dogs
   1 Not heard/Not at all annoyed
   2 Slightly annoyed
   3 Moderately annoyed
   4 Very annoyed
   5 Extremely annoyed

b. Thunder
   1 Not heard/Not at all annoyed
   2 Slightly annoyed
   3 Moderately annoyed
   4 Very annoyed
   5 Extremely annoyed

c. Street traffic such as cars, trucks or motorcycles
   1 Not heard/Not at all annoyed

2 Slightly annoyed
3 Moderately annoyed
4 Very annoyed
5 Extremely annoyed

d. Commercial Aircraft noise
1 Not heard/Not at all annoyed
2 Slightly annoyed
3 Moderately annoyed
4 Very annoyed
5 Extremely annoyed

e. Military aircraft noise
1 Not heard/Not at all annoyed
2 Slightly annoyed
3 Moderately annoyed
4 Very annoyed
5 Extremely annoyed

Length of Time in Current Home

C4 How long have you lived in this area?

_____ [enter number of years]
0 Less than 1 full year

As part of the research study, you will be asked to complete a short questionnaire each time you hear a sonic thump over a 2 week period. Please answer these questions as soon after hearing the noise as possible. The questions will ask things like what time you heard the sounds, your location, whether you were inside or outside, and how you reacted. We will also ask you to complete a short survey at the end of each day, telling us about the sounds you heard. We will contact you about your enrollment soon. Thank you!

Text Confirmation **(sent a few days before field test to confirm cell phone number):**

You recently volunteered for a NASA sponsored study. You are in the “reminder” group, so please click the link to verify: (Qualtrics generated small link).

Webpage text at link: This question is for confirmation that you received the reminder. Please select: “I received the text message” and press “submit”

Single Event Response Form

Formatted for administration by web and Smart Phone
Ability to "go back" provided within survey

Half of recruited subjects will receive reminder message prompts after each sonic thump and 2 – 3 other times throughout the day with the text in italics below.

Text message prompt:

"*Did you just hear a sonic thump? Please click on the survey link, indicate your location, and answer yes or no. Please complete the survey questions".*

Single Noise Event Time and Location

E1 Date of the sonic thump or reminder: [MM/DD/YY] [Enable selectable format on survey]

E2 Time of the sonic thump or reminder: Hour: Minute using 12 hour format presented in 15 minute increments with associated buttons

E3 Does the map correctly show your location at the time when you heard the sonic thump or received a reminder?
1. Yes [go to E6]
2. No [go to E4]

E4. Were you at home, at work, or somewhere else?
1. Home (or within a 5-minute walk of home) [go to E6]
2. Work (or within a 5-minute walk of work) [go to E6]
3. Somewhere else [go to E5]

E5 Please provide the nearest street address to your location at the time of the sonic thump or reminder:
[Text box for open ended address response]

E6 Did you hear a sonic thump?
1. Yes [go to E7]
2. No [go to E12]

Single Noise Event Response Ratings

E7 How much did the sonic thump **bother, disturb**, or **annoy** you?
1 Not at all annoyed

2 Slightly annoyed
3 Moderately annoyed
4 Very annoyed
5 Extremely annoyed

E8 How **loud** was the sonic thump?
1 Not at all loud
2 Slightly loud
3 Moderately loud
4 Very loud
5 Extremely loud

E9 How much did the sonic thump **interfere** with your activity?
1 No interference
2 Slightly interfering
3 Moderately interfering
4 Very interfering
5 Extremely interfering

E10 **Vibration** is a motion. The motion may be seen, felt or heard. **Rattle** is a type of noise that can occur when objects move due to a vibration. Did you see, hear, or feel **vibration** or **rattle**?
1. Yes
2. No

E11 Did the sonic thump **startle** you?
1. Yes
2. No

Single Event Environment

E12 How **loud was the background noise** at the time of the sonic thump or reminder?
1 Not heard/Not at all loud
2 Slightly loud
3 Moderately loud
4 Very loud
5 Extremely loud

E13 If you were indoors at the time of the sonic thump or reminder, were your windows open or closed?
1. Open
2. Closed
3. I was not indoors.

E14 Please enter any additional comments. [text box]

This information collection meets the requirements of 44 U.S.C § 3507 as amended by section 2 of the Paperwork Reduction Act of 1995. The OMB control number for this collection is 2700-0167, which expires on 8/31/2021. We estimate that it will take 2 minutes to read the instructions and answer the questions. Send any comments relating to our time estimate to NASA-QSF18@mail.nasa.gov.

Quiet Supersonic Flights 2018 Community Test
Daily Response to Sonic Thumps

Daily Summary Response Form

To be formatted for administration by web and Smart Phone
Ability to "go back" provided in survey

[Self-administered questionnaire completed at the end of each day]

D1 Date: MM/DD/YY [Enable selectable format on survey]

Overall Daily Summary

D2 Did you hear any sonic thumps today?
1 Yes, [go to D3]
2 No, [go to D5]

D3 Over the course of your day, how much did the sonic thumps bother, disturb, or annoy you?
1 Not at all annoyed
2 Slightly annoyed
3 Moderately annoyed
4 Very annoyed
5 Extremely annoyed

D4 Did any sonic thumps startle you today?

1. Yes
2. No

Daily Summary near Home

D5 Select all time periods that you were **at or near home** today. Select all that apply.
8 -9
9-10
10-11
11-12
12-1
1-2
2-3
3-4
4-5

D6 Select all time periods that you **at or near work** today. Select all that apply.

- 8 -9
- 9-10
- 10-11
- 11-12
- 12-1
- 1-2
- 2-3
- 3-4
- 4-5

D7 Please enter any additional comments. [text box]

This information collection meets the requirements of 44 U.S.C § 3507 as amended by section 2 of the Paperwork Reduction Act of 1995. The OMB control number for this collection is 2700-0167, which expires on 8/31/2021. We estimate that it will take 2 minutes to read the instructions and answer the questions. Send any comments relating to our time estimate to NASA-QSF18@mail.nasa.gov.

Quiet Supersonic Flights 2018

Post Test Feedback Survey

Thank you for your recent participation in this research study!

F1 Please provide feedback on the length and clarify of the questionnaires in the table using the scale provided.

1 Agree strongly
2 Agree somewhat
3 Undecided
4 Disagree somewhat
5 Disagree strongly

	Agree strongly	Agree	Undecided	Disagree	Disagree Strongly
	1	2	3	4	5
Single Event Survey **after each sonic thump**					
The questions were easy to understand					
The questions were easy to answer					
The questionnaire was easy to complete					
The questionnaire was a good length					
Daily Summary Survey **At End of Day**					
The questions were easy to understand					
The questions were easy to answer					
The questionnaire was easy to complete					
The questionnaire was a good length					
Geo-location					
The Geo-location application was easy to use					
I didn’t understand the geo-location application					
My location was never right					
My location was mostly right					
My location was always right					
It was easy to enter my location if needed					

F2. Please provide some adjectives that you feel best describe the sonic thump. What sound does it compare to?

F3 Were the survey reminders helpful?

1 Yes

2 No

F4. Please provide additional feedback or comments so that we can improve our survey methods.

Thank you. We appreciate your help with this research study!

K. QSF18 Survey Instruments Screen Shots

The following pages provide Appendix K. This appendix file is provided separately from the main body of the report.

QSF18 Survey Instruments Screen Shots

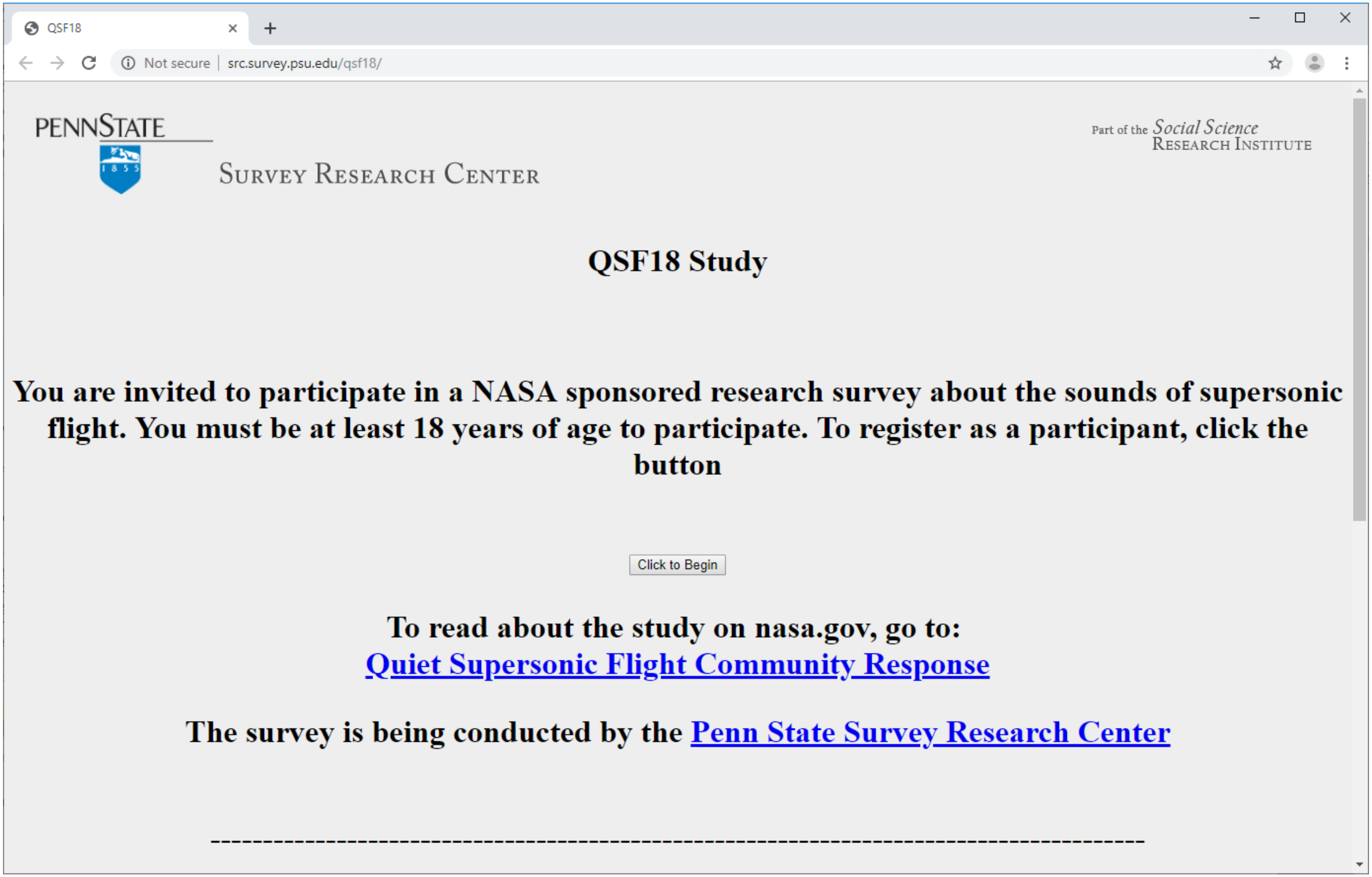
Contents

QSF18 Introductory and Background Surveys, and Text Confirmation

Introductory Page, Implied Informed Consent and Eligibility

The QSF 18 survey link is: http://src.survey.psu.edu/qsf18/

The QSF 18 Introductory page is shown as follows. All surveys are timed stamped, both start and finish.


QSF18

Not secure | src.survey.psu.edu/qsf18/

PENNSTATE

1855

SURVEY RESEARCH CENTER

Part of the Social Science Research Institute

QSF18 Study

You are invited to participate in a NASA sponsored research survey about the sounds of supersonic flight. You must be at least 18 years of age to participate. To register as a participant, click the button

Click to Begin

To read about the study on nasa.gov, go to:
Quiet Supersonic Flight Community Response

The survey is being conducted by the Penn State Survey Research Center

Implied Consent

QSF18 | Online Survey Software | Qualtrics

pennstate.qualtrics.com/jfe/form/SV_eEWeMqcOveKIGTH

PennState

This information collection meets the requirements of 44 U.S.C § 3507 as amended by section 2 of the Paperwork Reduction Act of 1995. The OMB control number for this collection is 2700-0167, which expires on 8/31/2021. We estimate that it will take 15 minutes to read the instructions and answer the questions. Send any comments relating to our time estimate to NASA-QSF18@mail.nasa.gov.

QSF18 Implied Consent and Background Survey

Smart phone/web based implementation

Thank you for volunteering to participate in this NASA research study to gather opinions about the perception of sonic thumps. There will be a maximum of 500 participants. We appreciate your participation, which is voluntary and confidential. You will receive compensation of $25 per week

QSF18 | Online Survey Software | Qualtric

pennstate.qualtrics.com/jfe/form/SV_eEWeMqcOveKIGTH

for the two weeks of the survey for a total amount of $50 as an expression of appreciation. If the survey is terminated before the end of the first week, participants who completed the survey until its termination will receive $25. If the survey is terminated after the first week, but before the end of the second week, participants who completed the survey until its termination will receive $50. If there is a question you do not want to answer, you may skip that question and move on to the next question. Your responses will be associated with your participant number and summarized so that the answers you provide cannot be associated with you or your household. You must be 18 years of age or older to consent to participate in this research. ***Responding to the survey questions implies your consent to participate in this background survey, and in the upcoming two week research study.***

During the research study you will go about your normal activities, and there will be supersonic flights in your area. The flights will produce audible sounds called sonic thumps. This muffled sound is very different from the sonic booms you have heard about – or may actually have heard – in the past. In fact, you may not even hear the sonic thumps at all. When a sonic thump occurs, you will be asked to provide information about your location and your perception of the sound. There are no foreseeable risks or discomforts associated with participating in this research.

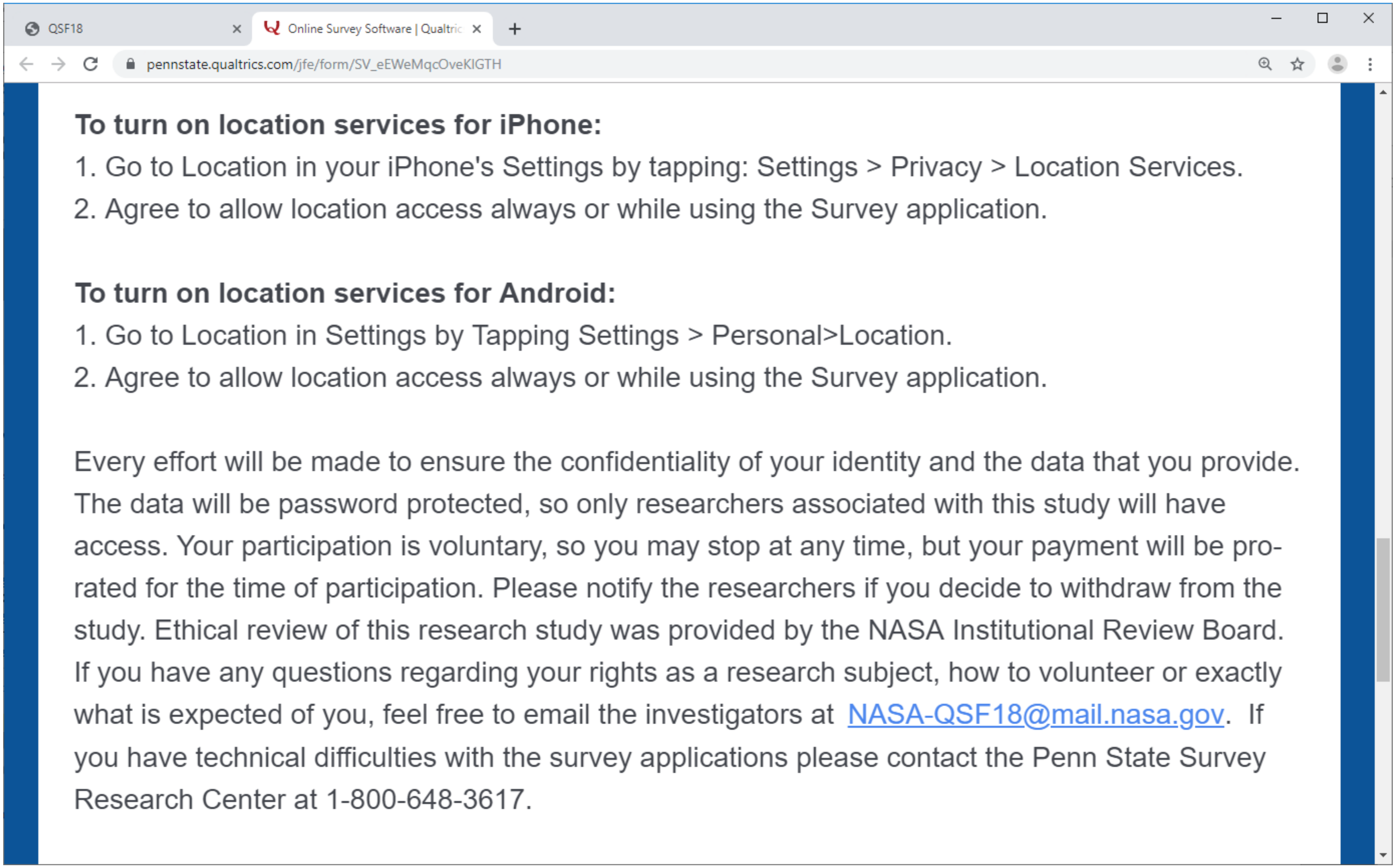
You will be randomly assigned into one of two groups, one that receives reminders to listen for

QSF18 | Online Survey Software | Qualtric

pennstate.qualtrics.com/jfe/form/SV_eEWeMqcOveKIGTH

sonic thumps, and one that does not. The “no reminder” participants will simply respond when they hear a sonic thump. If you are in the reminder group, you will be sent reminders throughout the day. The message will read: “Did you just hear a sonic thump? Please click on the survey link, indicate your location, and answer yes or no. Please complete the survey questions”. This message will sometimes, but not always, be sent after a sonic thump and sometimes just as a reminder to listen. For all participants, please provide your responses as soon as possible after hearing each sonic thump. If you are driving when the sonic thump occurs, please wait until you have stopped driving. You will also be asked to complete a short daily survey at the end of each day, providing a rating of your perception of the sounds overall during that particular day. At the end of the research study we will provide the opportunity for your feedback on the surveys.

Participants have the option to use their own smart phones or other mobile devices to respond using the Qualtrics app, a mobile survey tool. Alternatively, you may choose to complete the surveys on the web. If you use your mobile device, we ask that you have location services activated on the mobile device you use to complete the survey. Your response location is required so that we can associate your location with the sound measured at the nearest noise monitor. You will need either Wi-Fi or Cellular connection access in order for your device to respond. ***Please ensure that location services is turned on when you respond to the surveys.***



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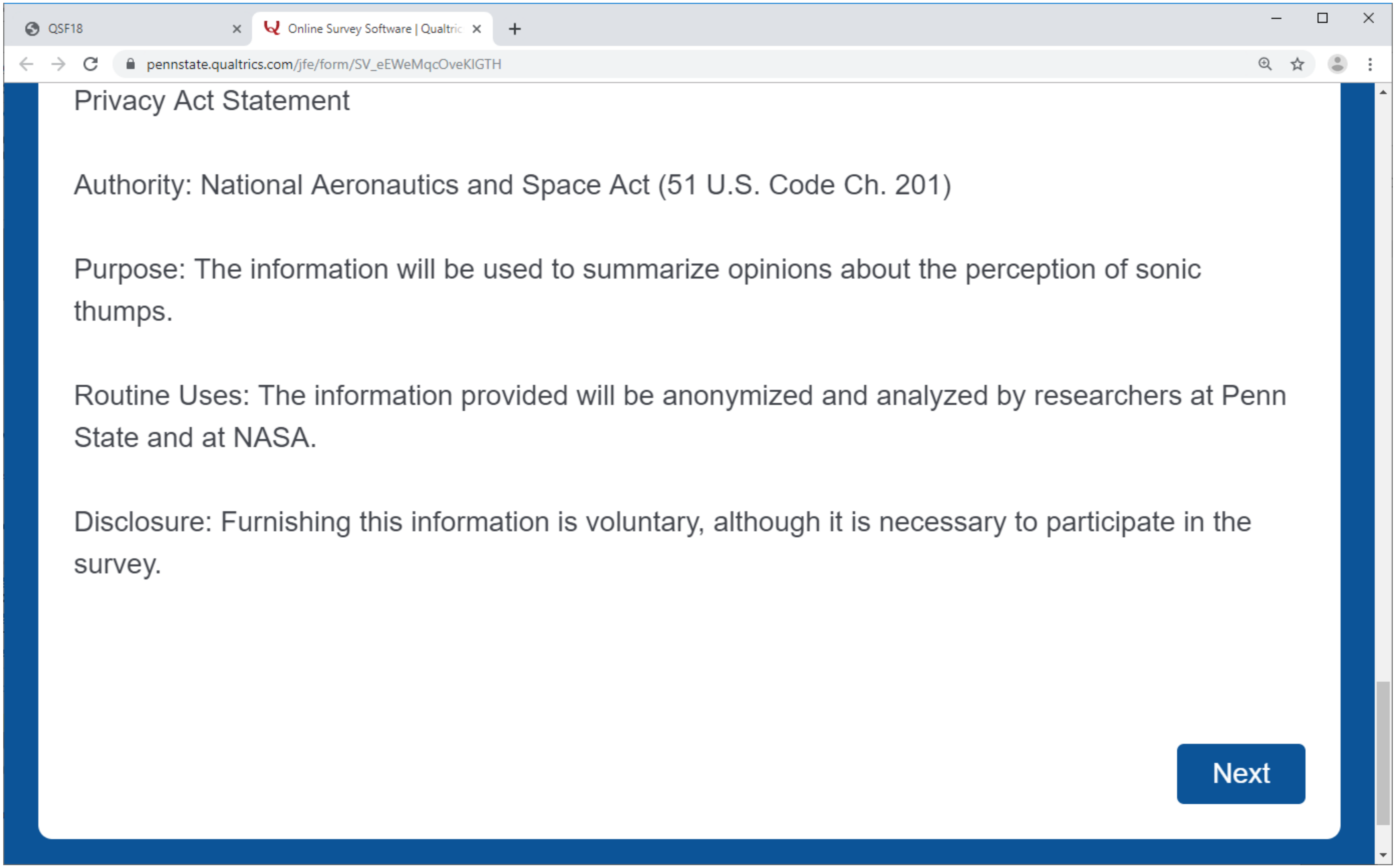
To turn on location services for iPhone:

1. Go to Location in your iPhone's Settings by tapping: Settings > Privacy > Location Services.
2. Agree to allow location access always or while using the Survey application.

To turn on location services for Android:

1. Go to Location in Settings by Tapping Settings > Personal>Location.
2. Agree to allow location access always or while using the Survey application.

Every effort will be made to ensure the confidentiality of your identity and the data that you provide. The data will be password protected, so only researchers associated with this study will have access. Your participation is voluntary, so you may stop at any time, but your payment will be pro-rated for the time of participation. Please notify the researchers if you decide to withdraw from the study. Ethical review of this research study was provided by the NASA Institutional Review Board. If you have any questions regarding your rights as a research subject, how to volunteer or exactly what is expected of you, feel free to email the investigators at NASA-QSF18@mail.nasa.gov. If you have technical difficulties with the survey applications please contact the Penn State Survey Research Center at 1-800-648-3617.



Privacy Act Statement

Authority: National Aeronautics and Space Act (51 U.S. Code Ch. 201)

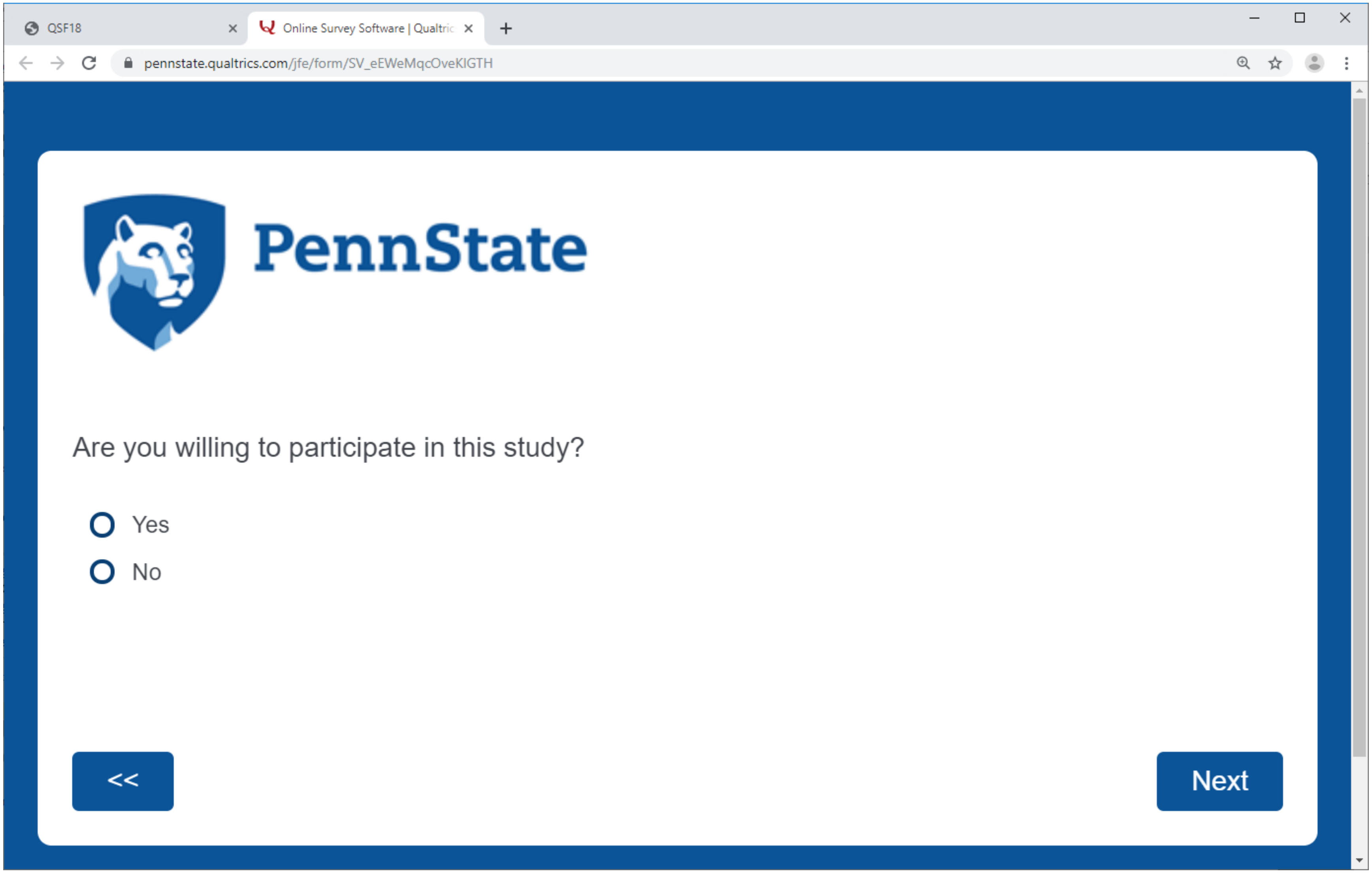
Purpose: The information will be used to summarize opinions about the perception of sonic thumps.

Routine Uses: The information provided will be anonymized and analyzed by researchers at Penn State and at NASA.

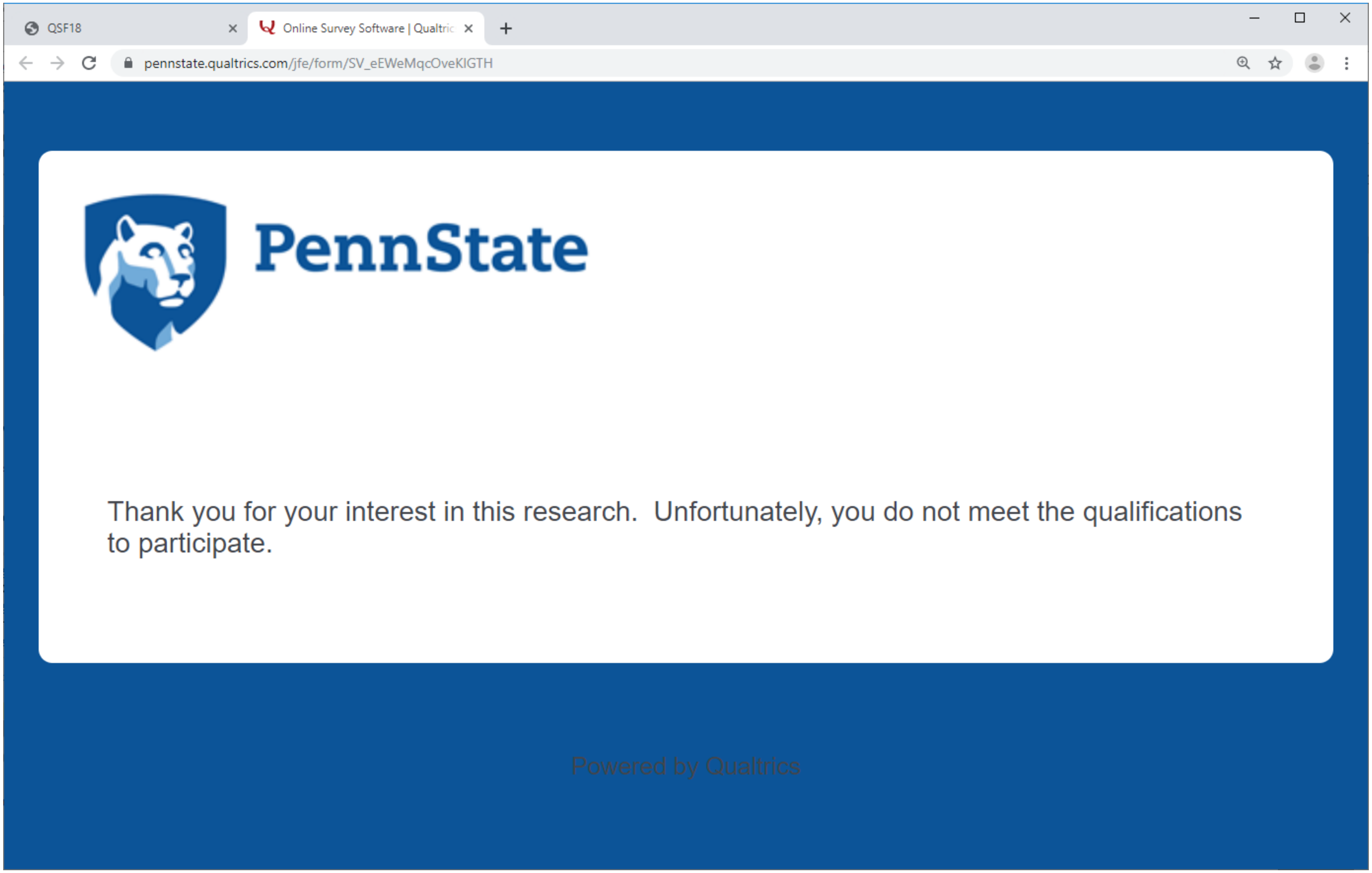
Disclosure: Furnishing this information is voluntary, although it is necessary to participate in the survey.

Next

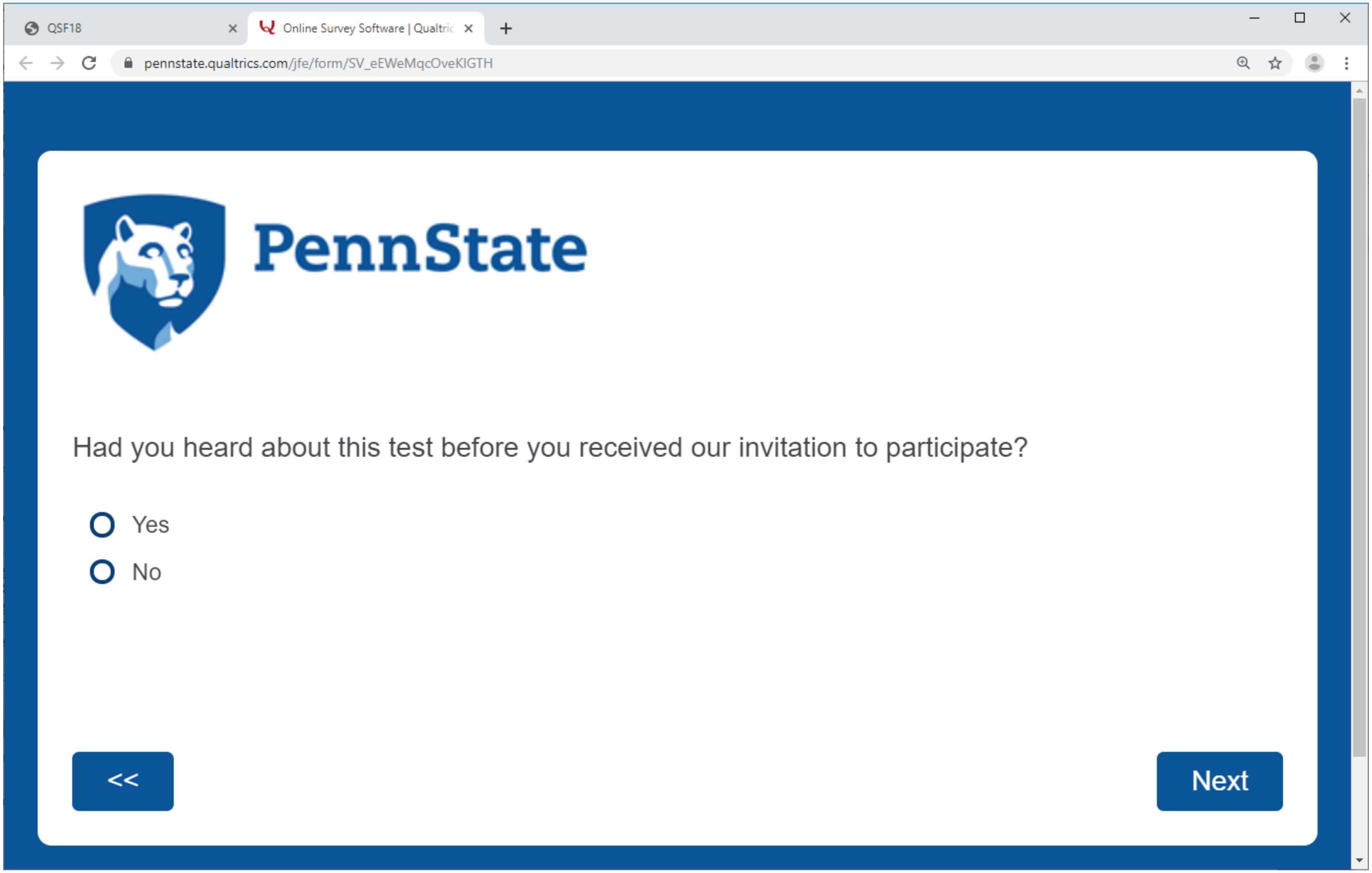
Eligibility to Participate



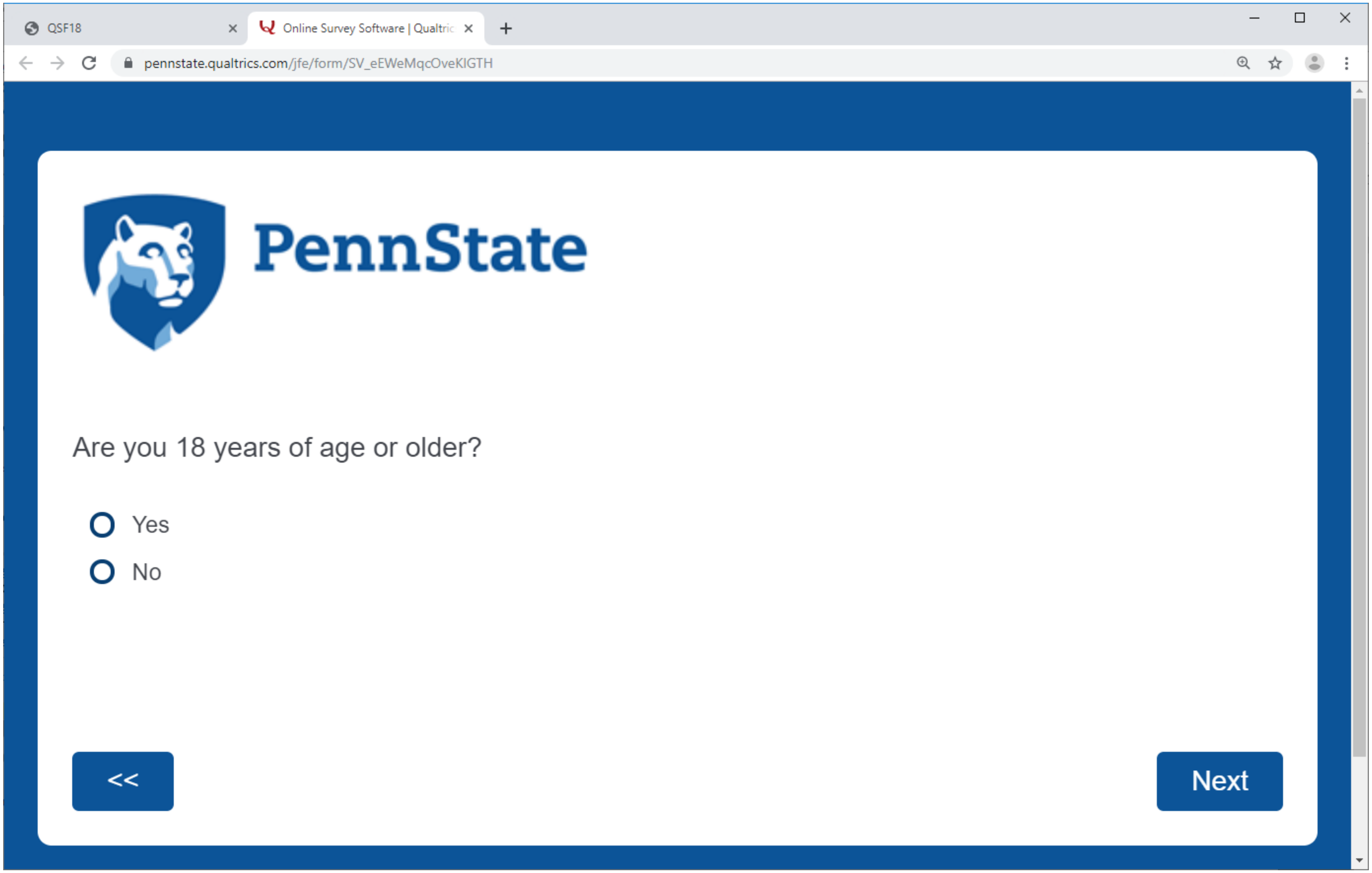
If the answer to willing to participate is No:



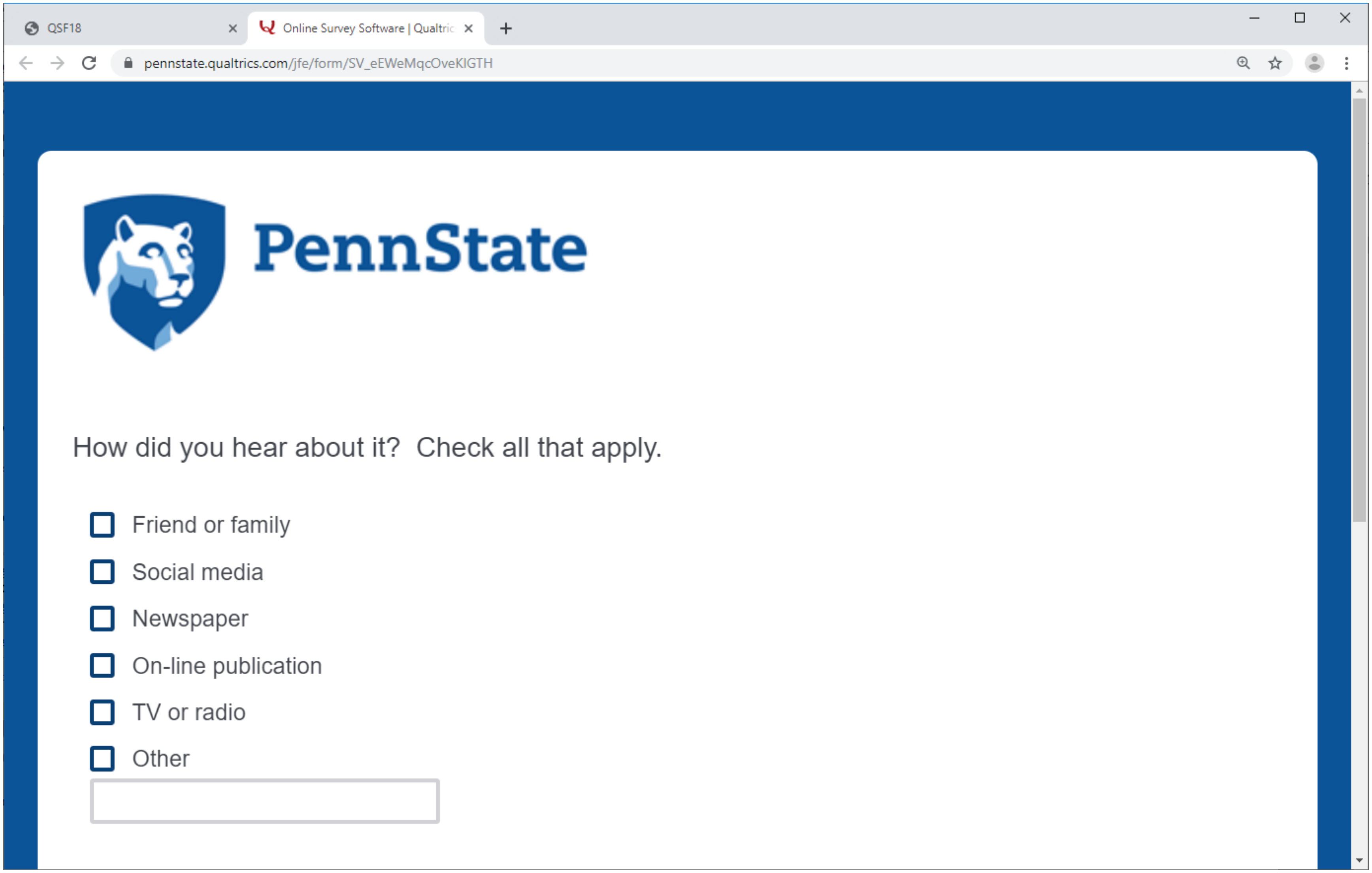
If the answer to willing to participate is yes, then inquire about prior media exposure:

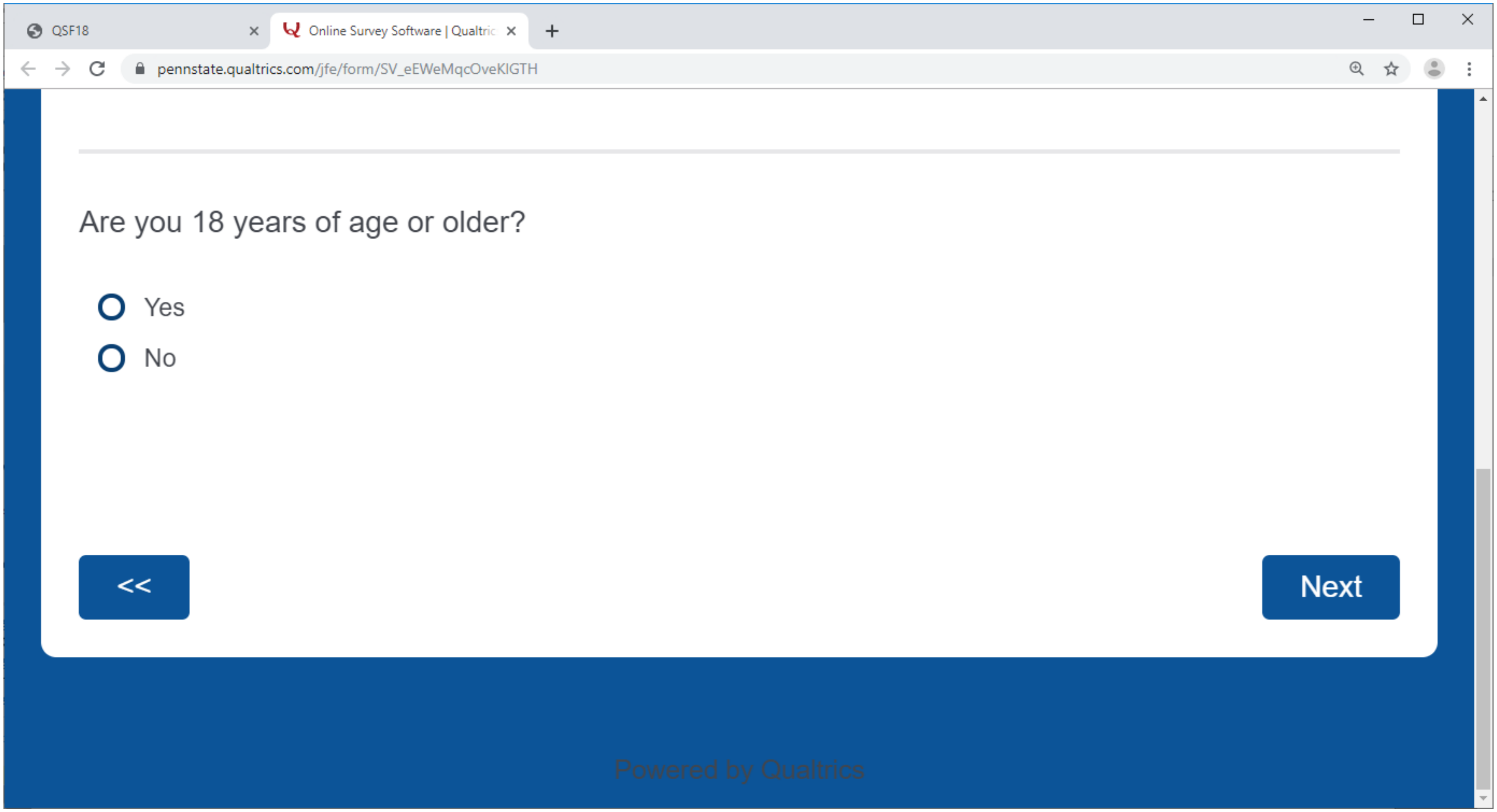


If the answer to prior media exposure is No, inquire about age:



If the answer to prior media exposure is Yes, inquire about media sources and age:

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Are you 18 years of age or older?
Yes
No
<<
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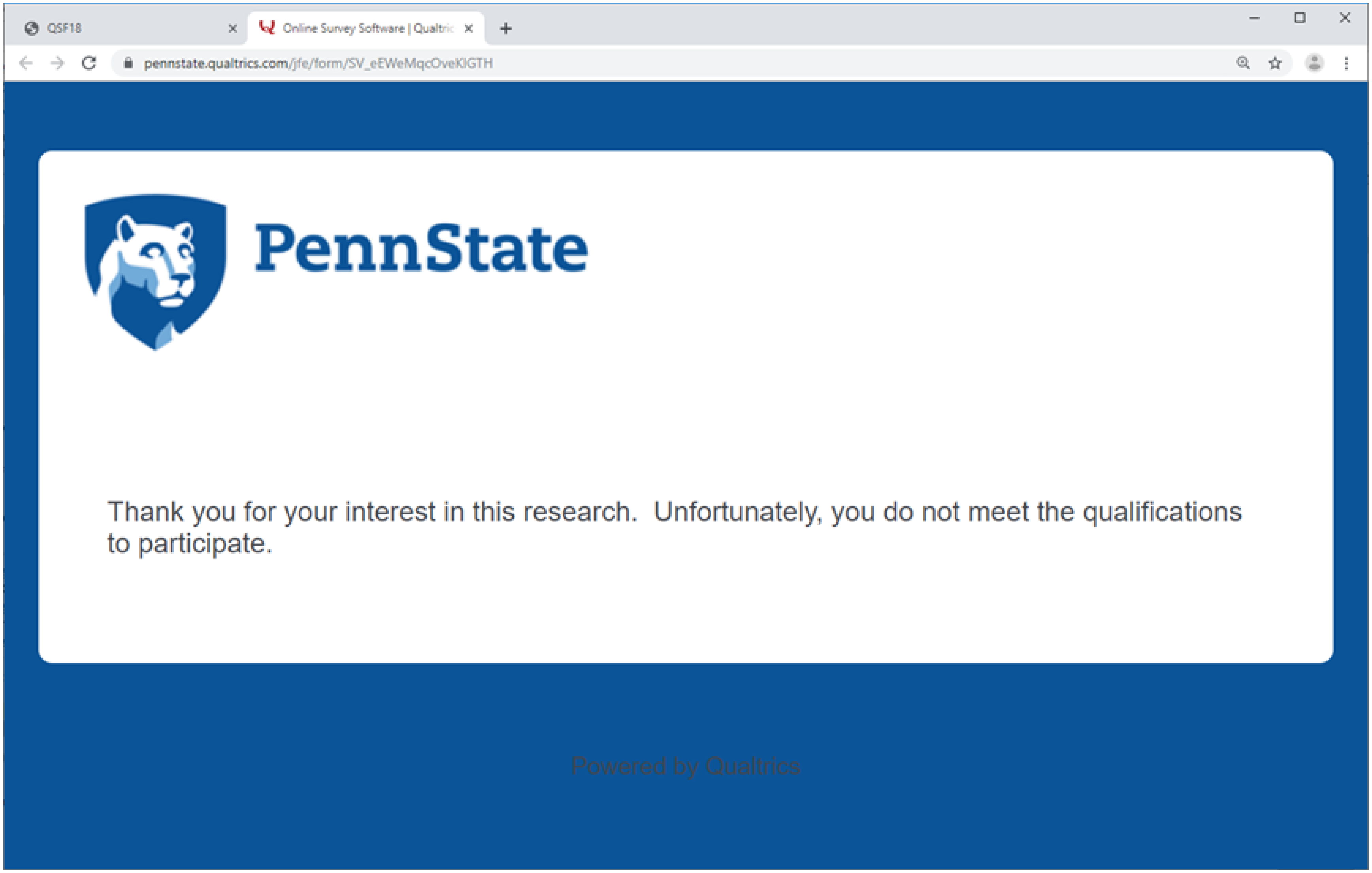
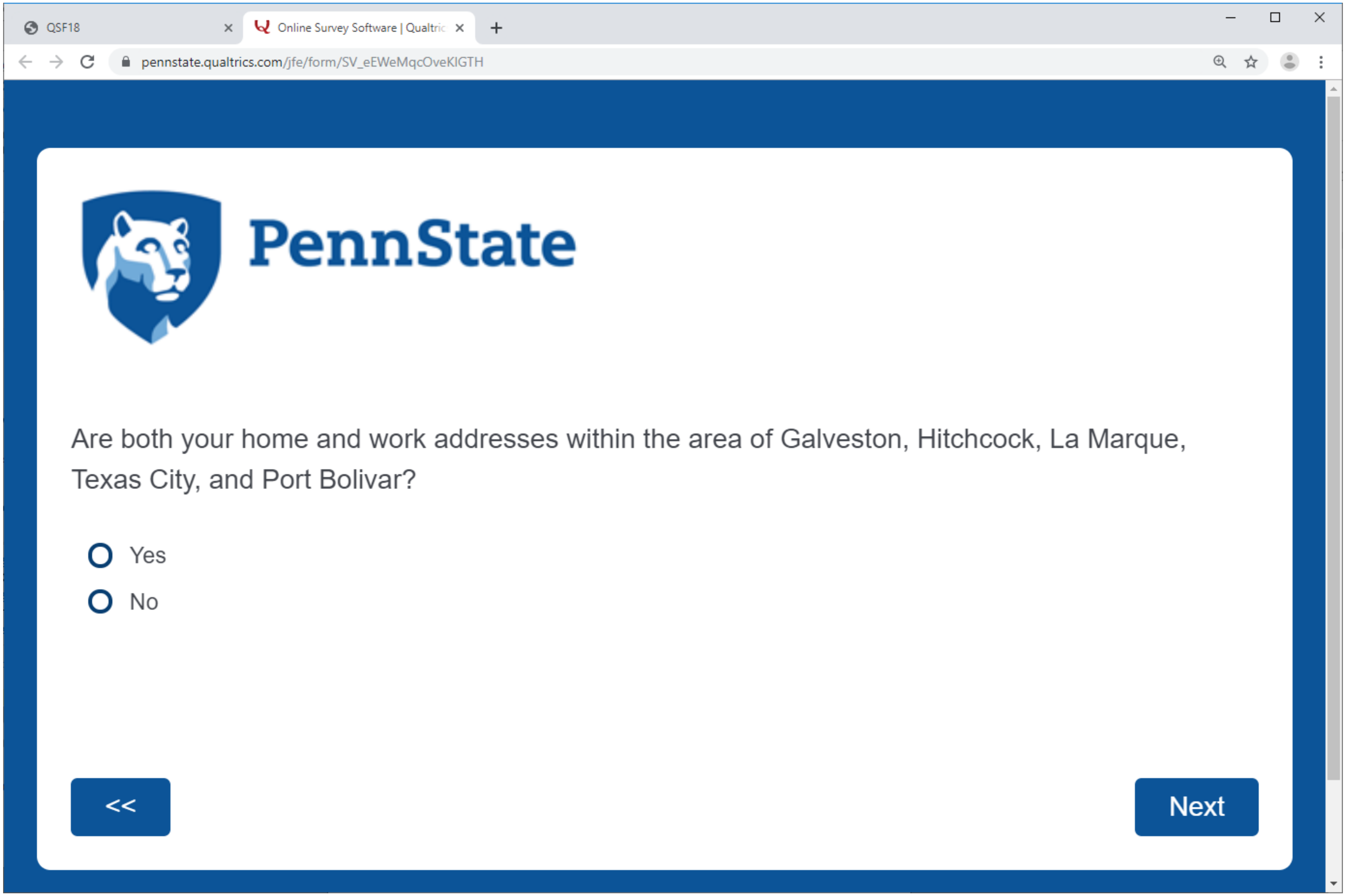
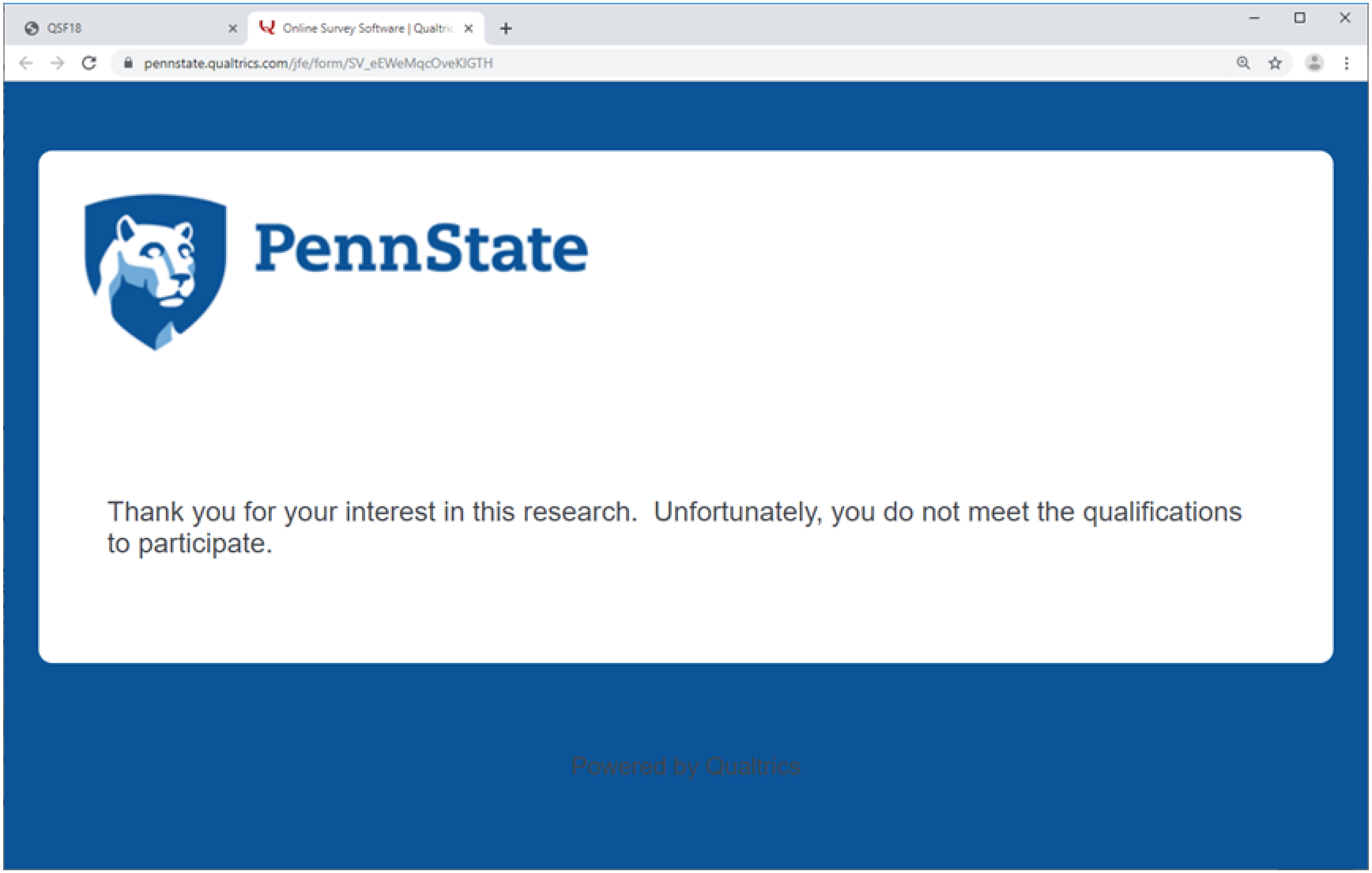
In either case, if answer to 18 years of age or older is No:



In either case, if answer to 18 years of age or older is Yes, inquire about locations:



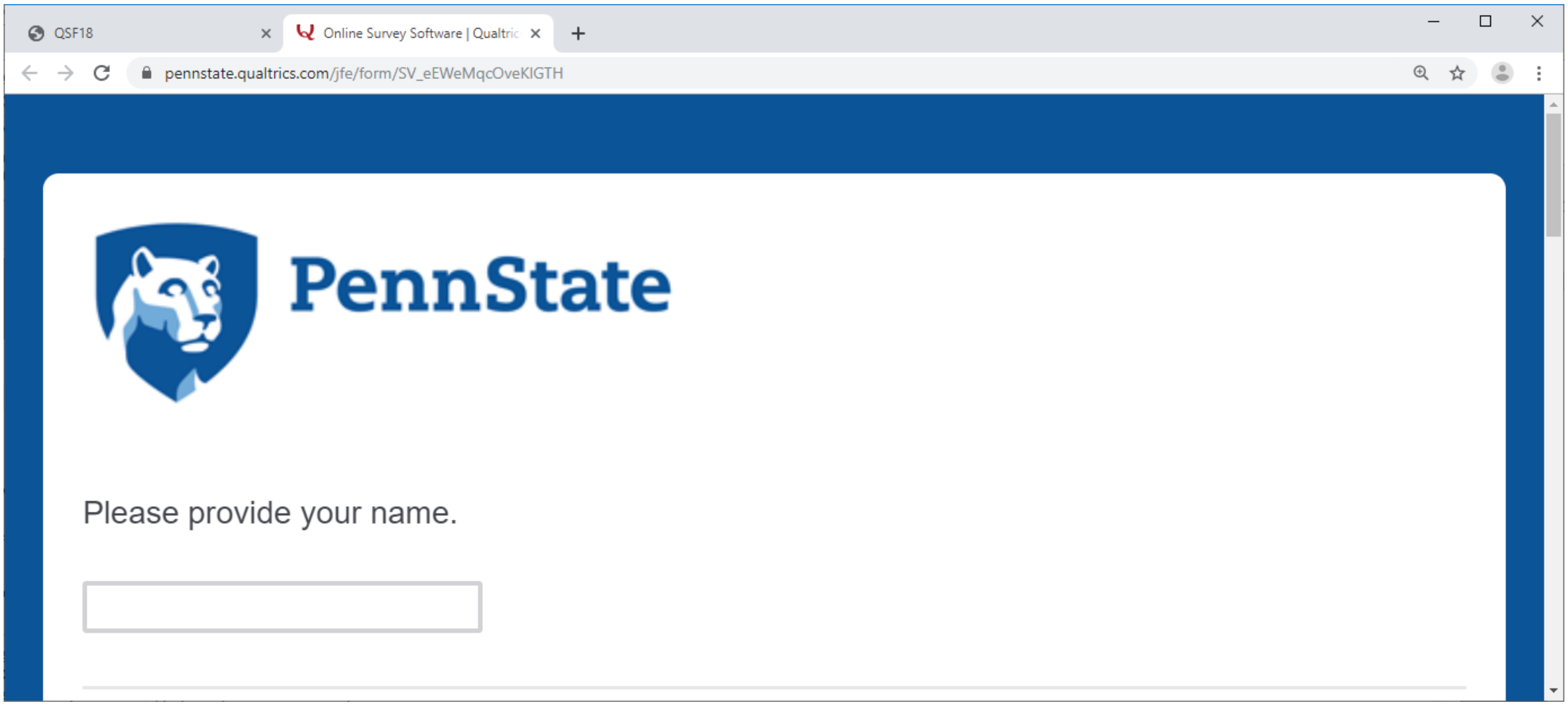
If locations answer is No:

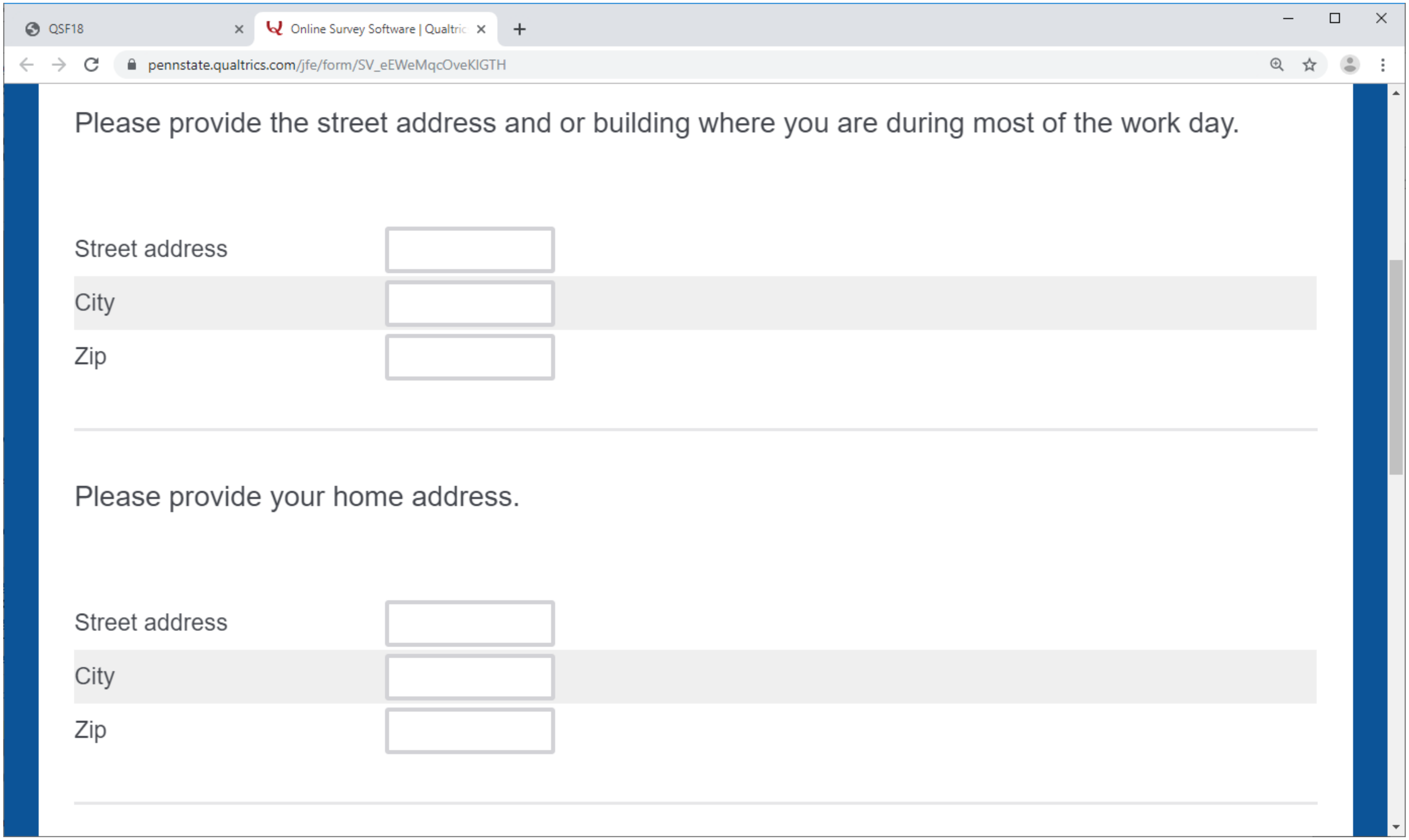


If locations answer is Yes, then informed consent and participation eligibility portion of survey is complete. Survey proceeds to background portion.

Background Survey

The background portion is the next section of the survey, and does not provide reverse navigation to informed consent and eligibility portion of survey.





Please provide the street address and or building where you are during most of the work day.

Street address

City

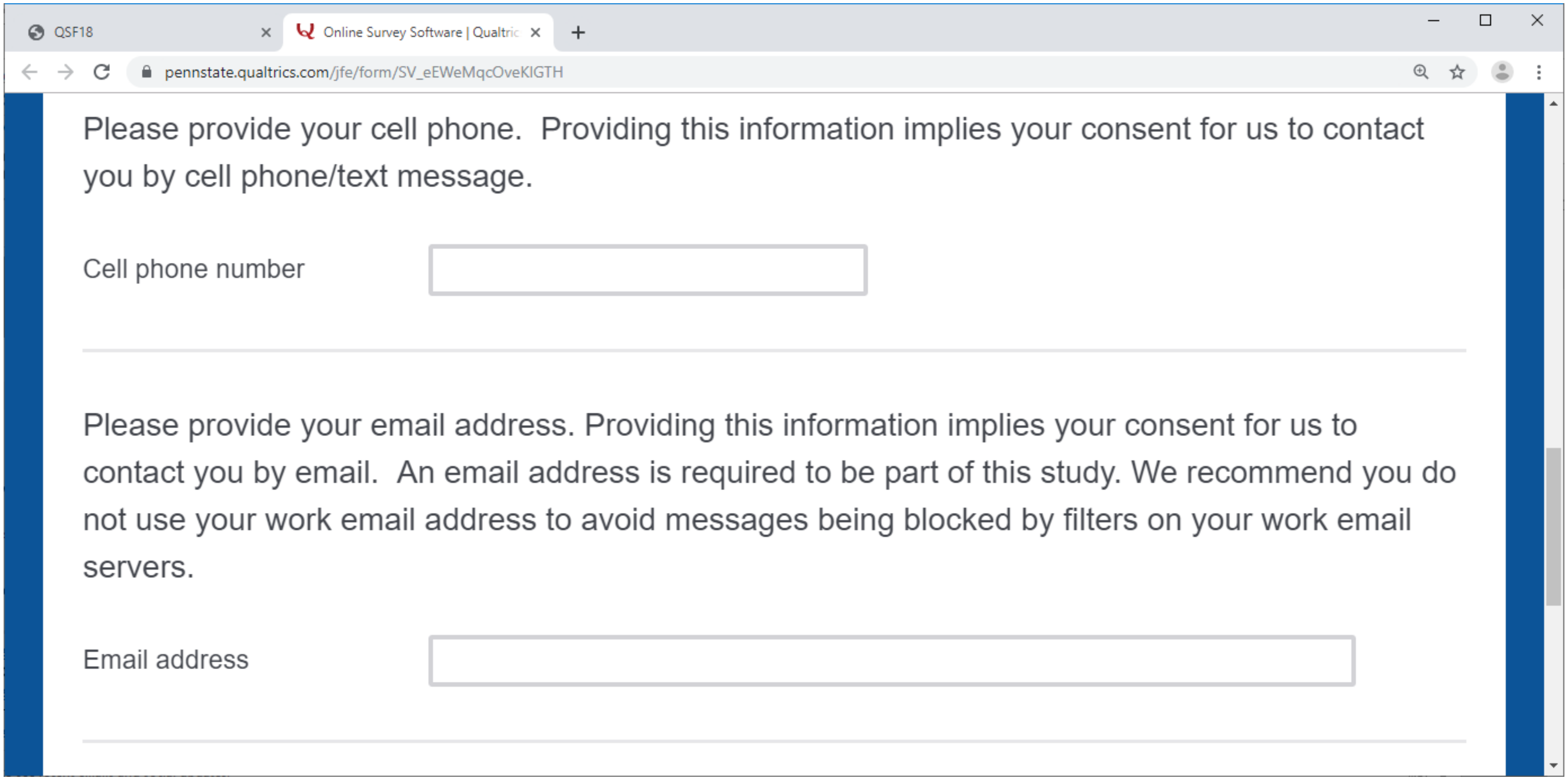
Zip

Please provide your home address.

Street address

City

Zip



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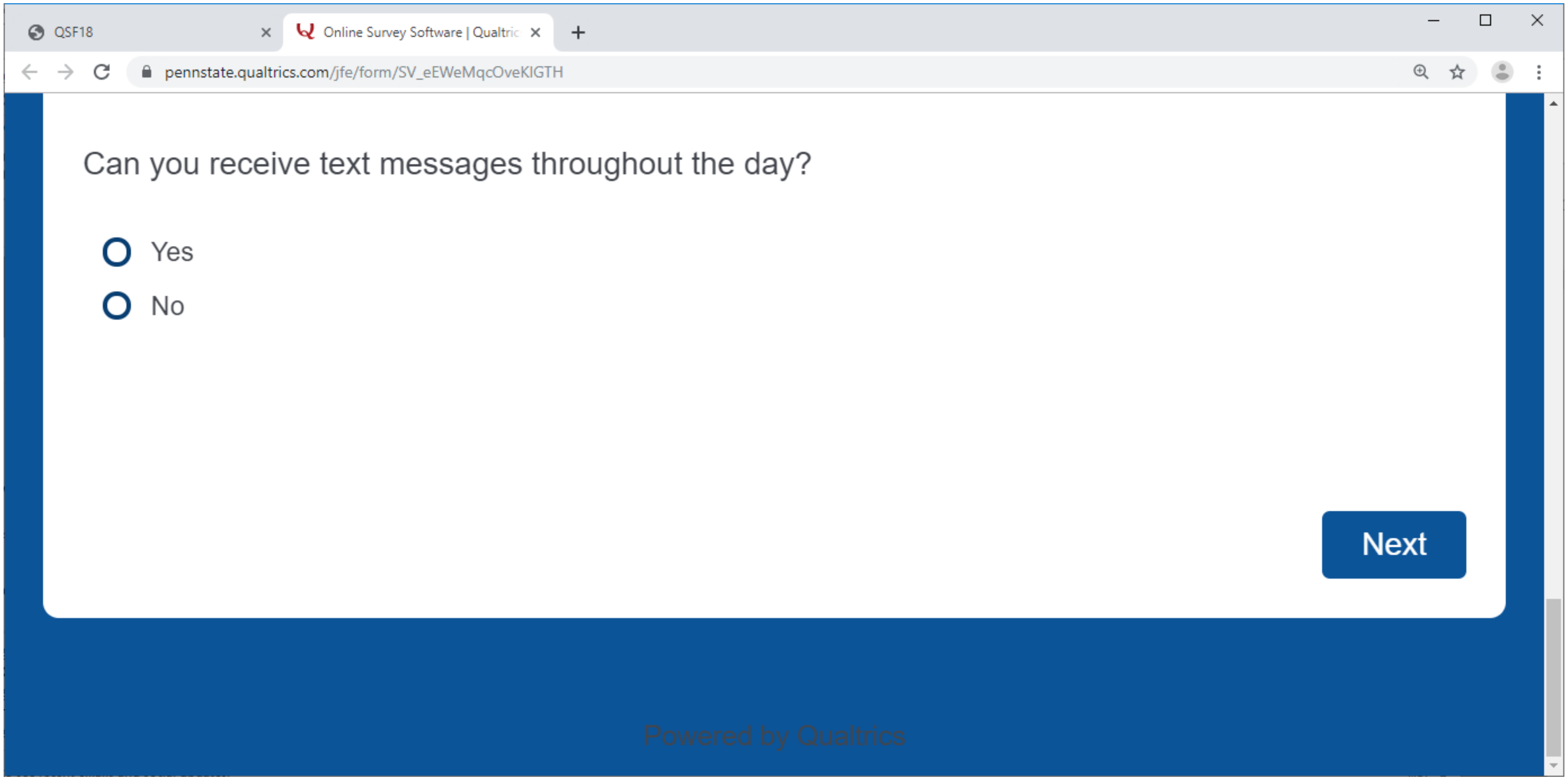
Please provide your cell phone. Providing this information implies your consent for us to contact you by cell phone/text message.

Cell phone number

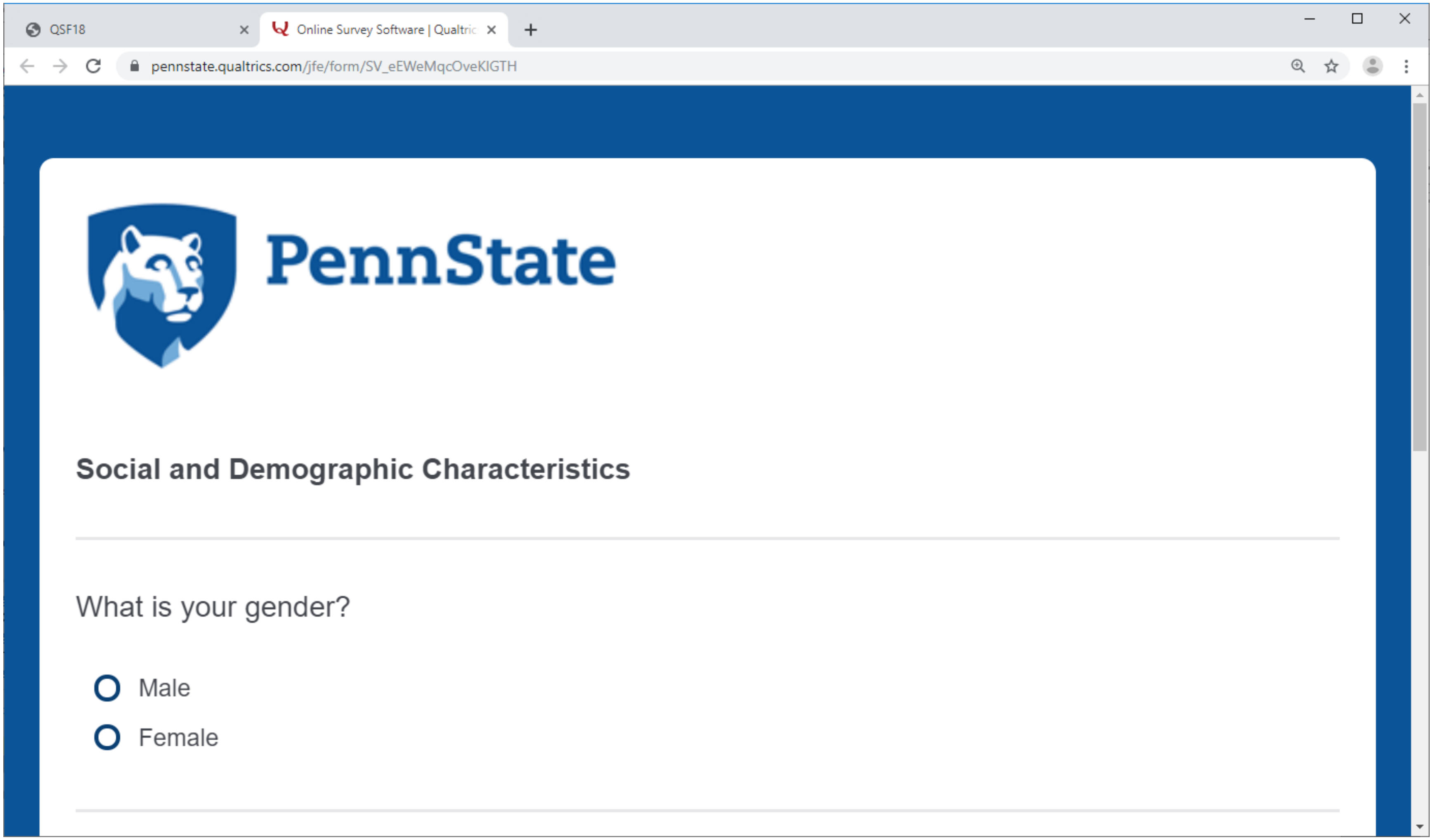
Please provide your email address. Providing this information implies your consent for us to contact you by email. An email address is required to be part of this study. We recommend you do not use your work email address to avoid messages being blocked by filters on your work email servers.

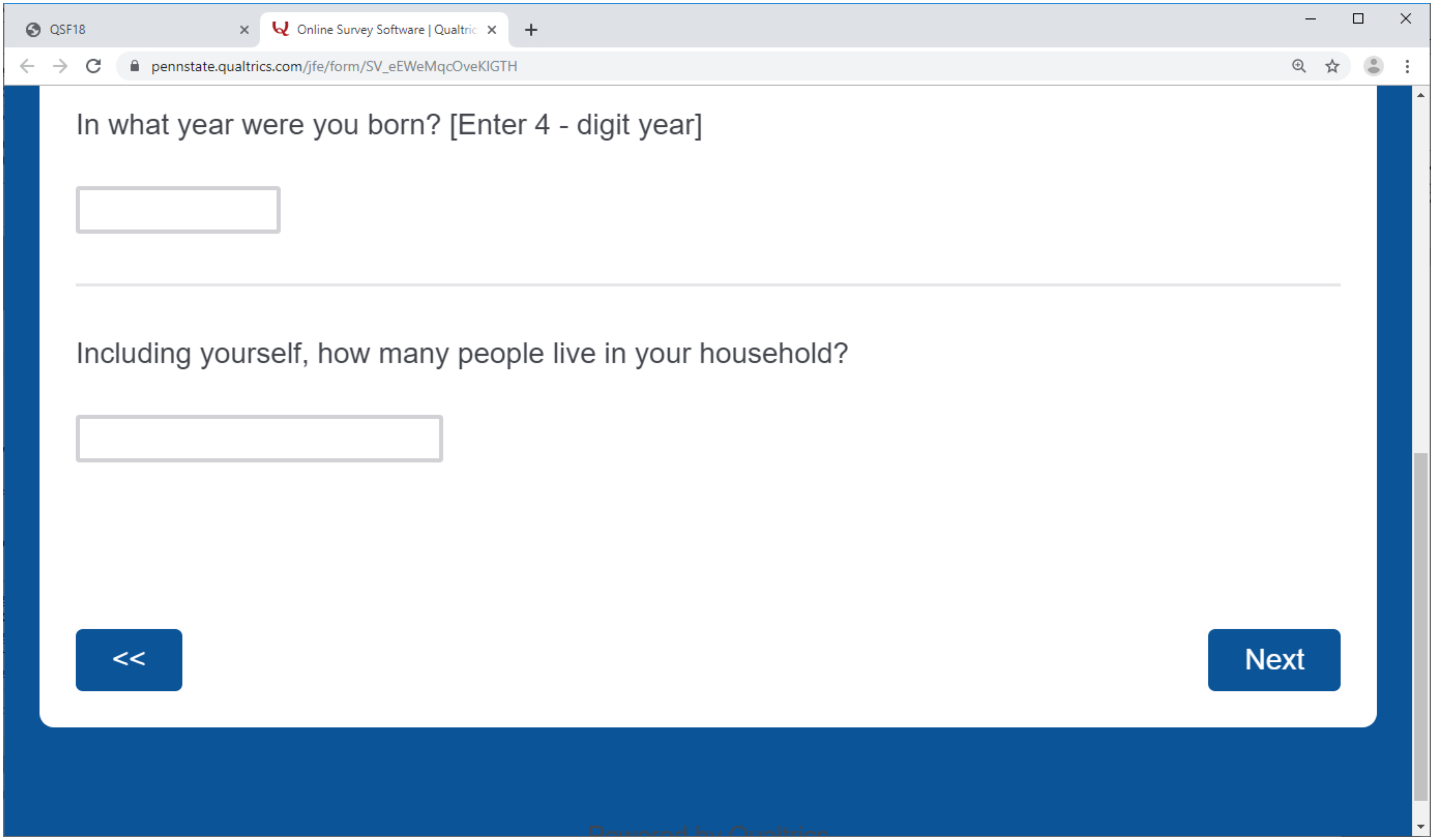
Email address



Participant must provide cell phone number or email address to proceed.

Social and Demographic Characteristics

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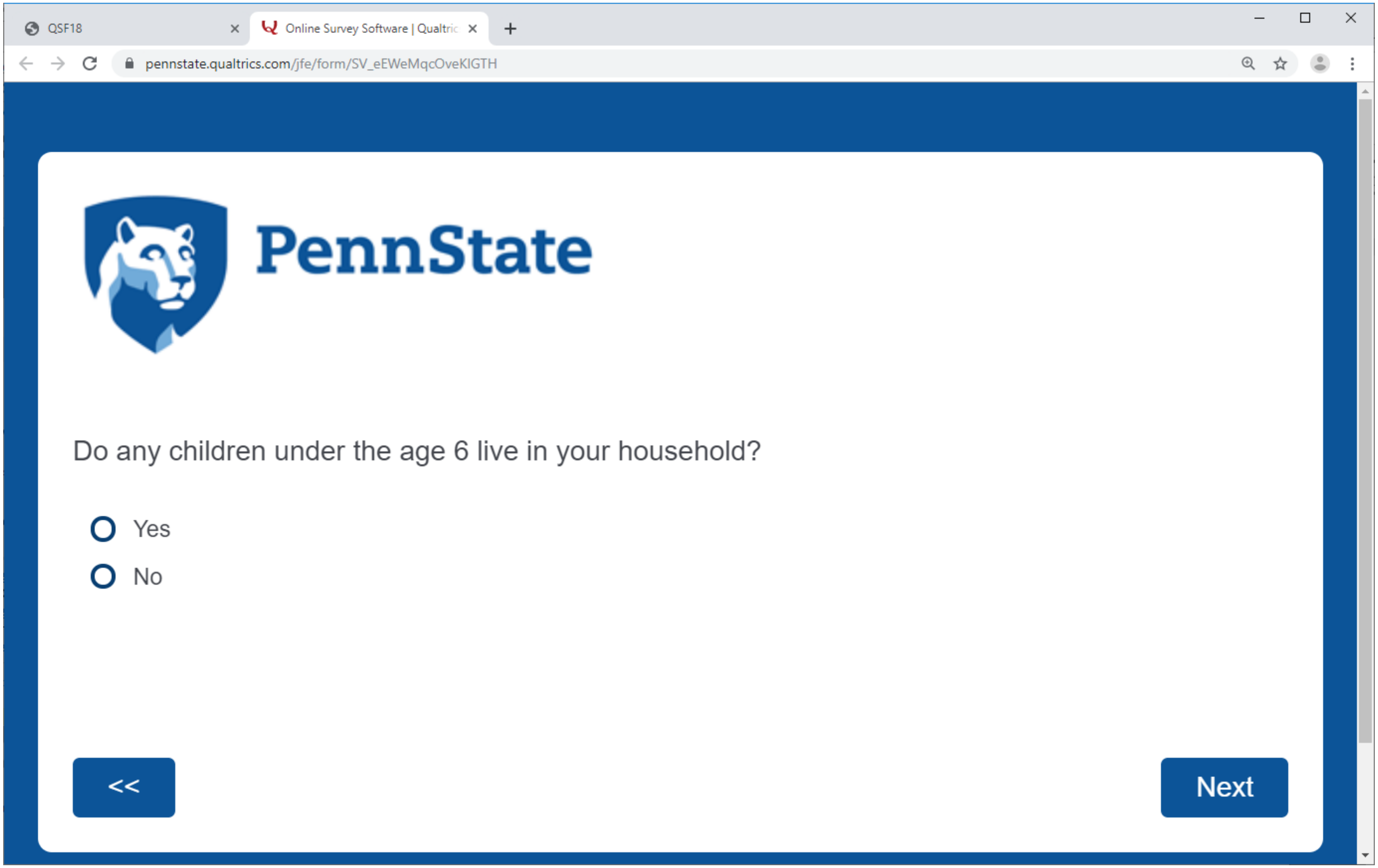
In what year were you born? [Enter 4 - digit year]
Including yourself, how many people live in your household?
<<
Next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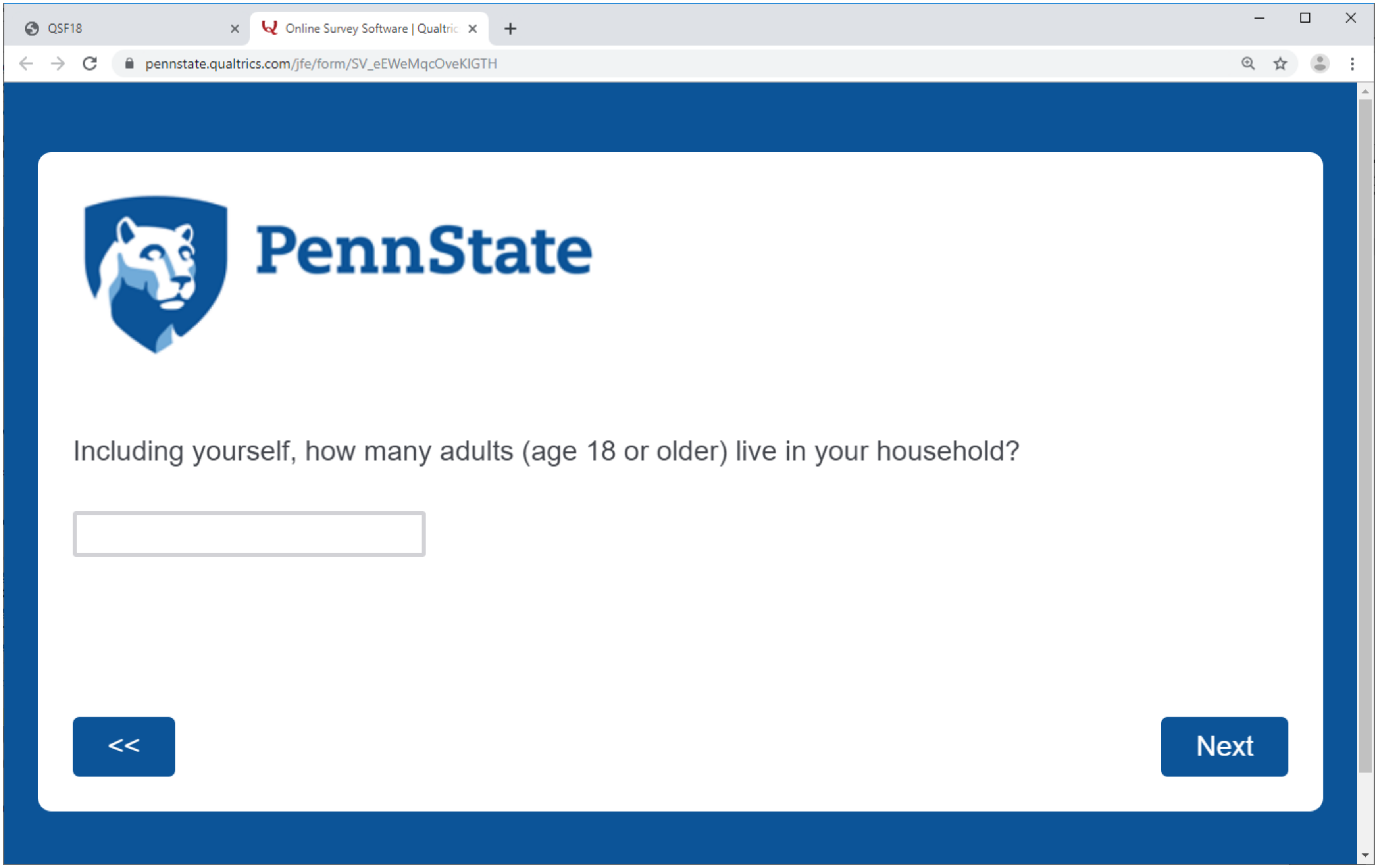
PennState
Do any children under the age 6 live in your household?
Yes
No
<<
Next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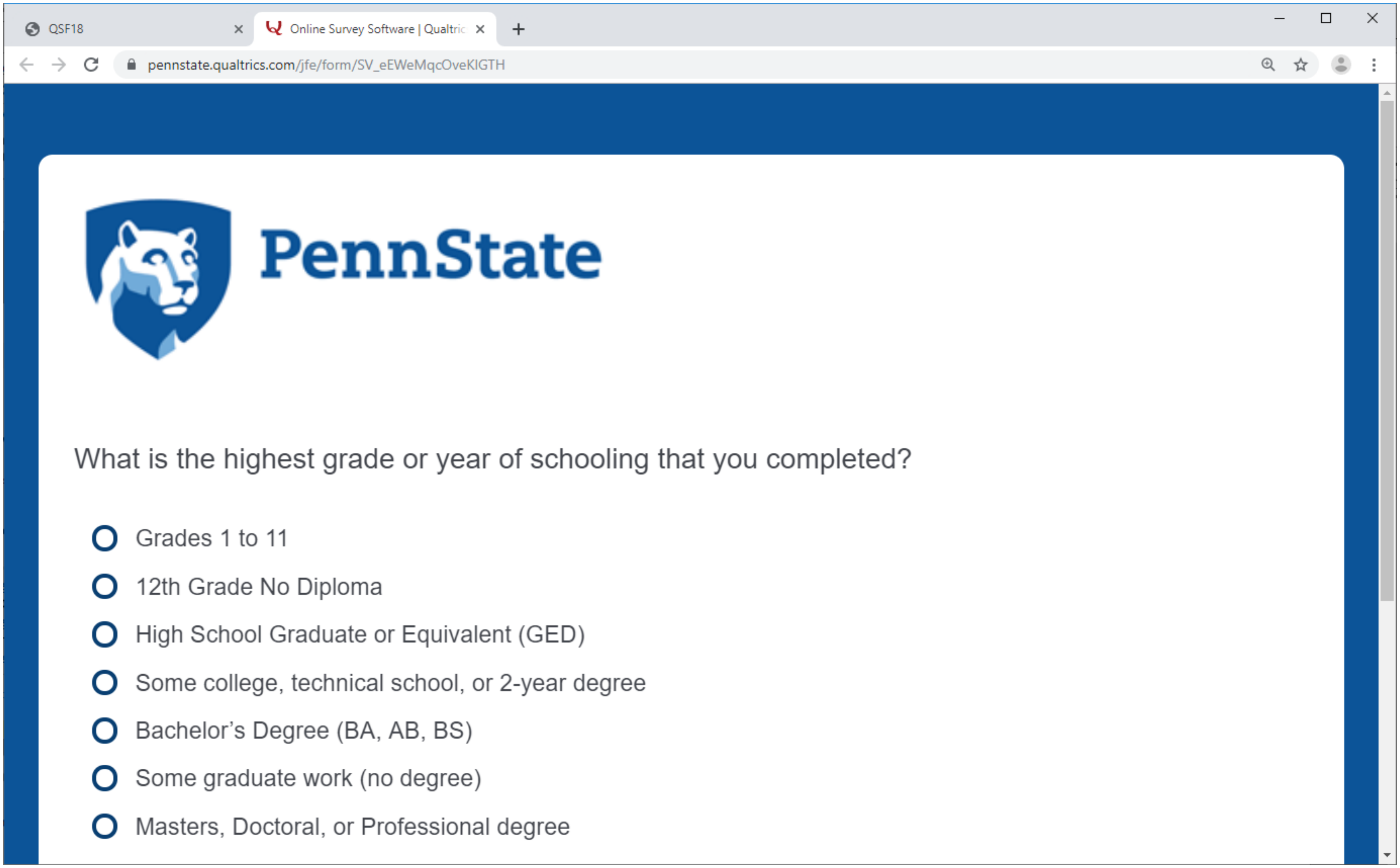
pennstate.qualtrics.com/jfe/form/SV_eEWeMqcOveKIGTH
PennState
Including yourself, how many adults (age 18 or older) live in your household?
<<
Next



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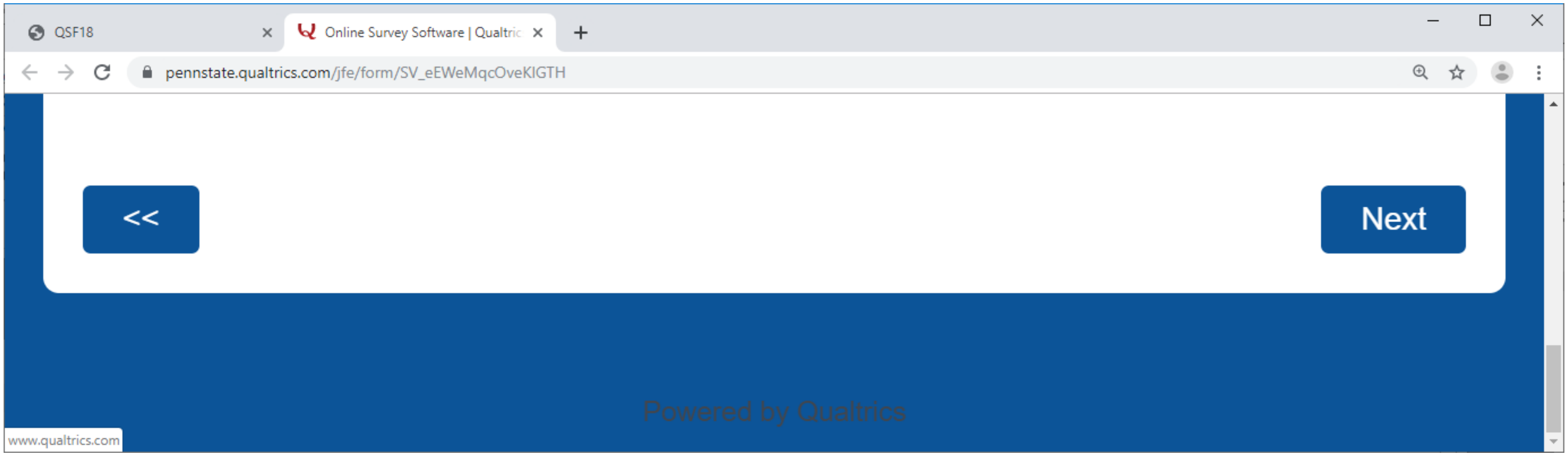
PennState

What is the highest grade or year of schooling that you completed?

- Grades 1 to 11
- 12th Grade No Diploma
- High School Graduate or Equivalent (GED)
- Some college, technical school, or 2-year degree
- Bachelor's Degree (BA, AB, BS)
- Some graduate work (no degree)
- Masters, Doctoral, or Professional degree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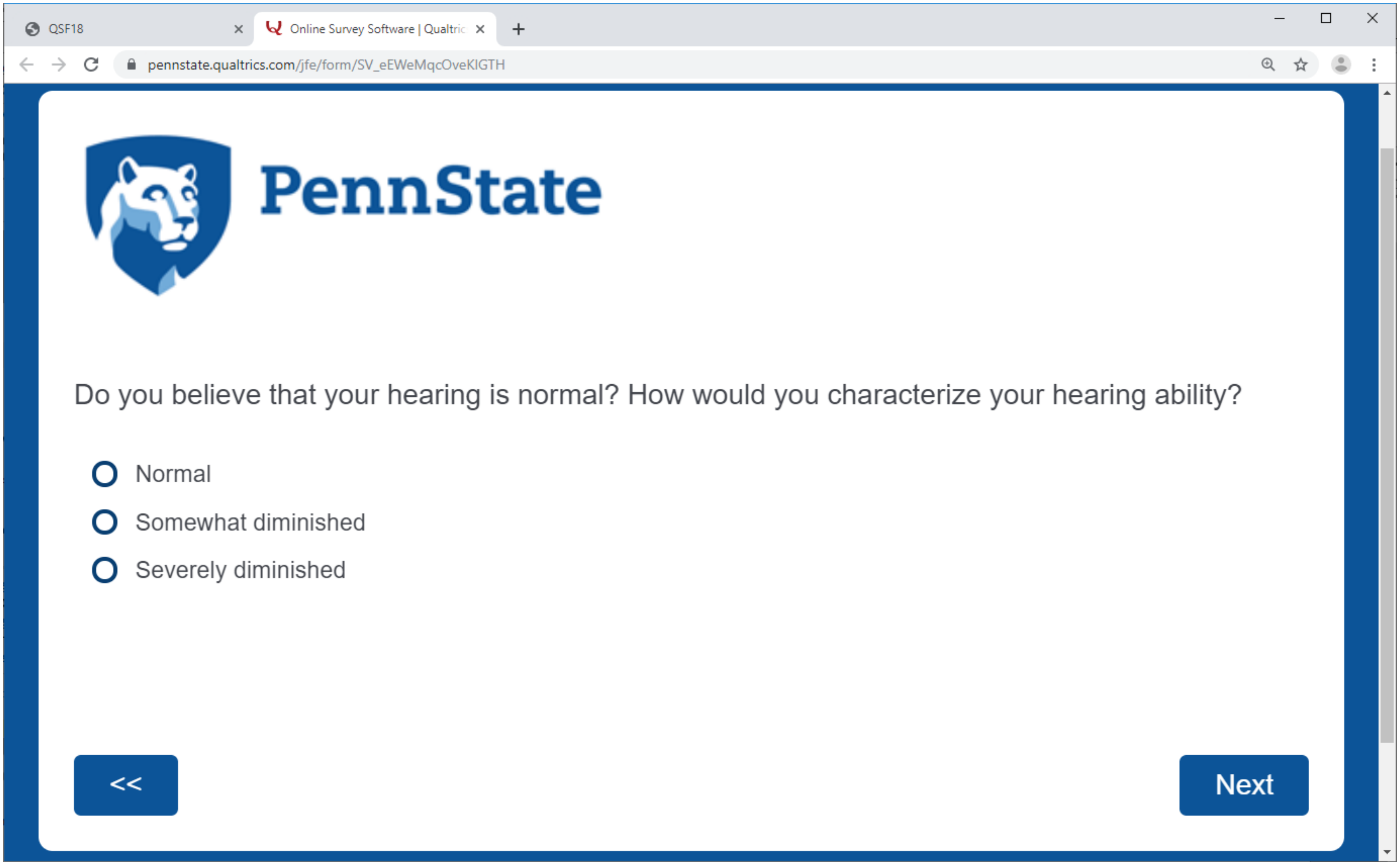
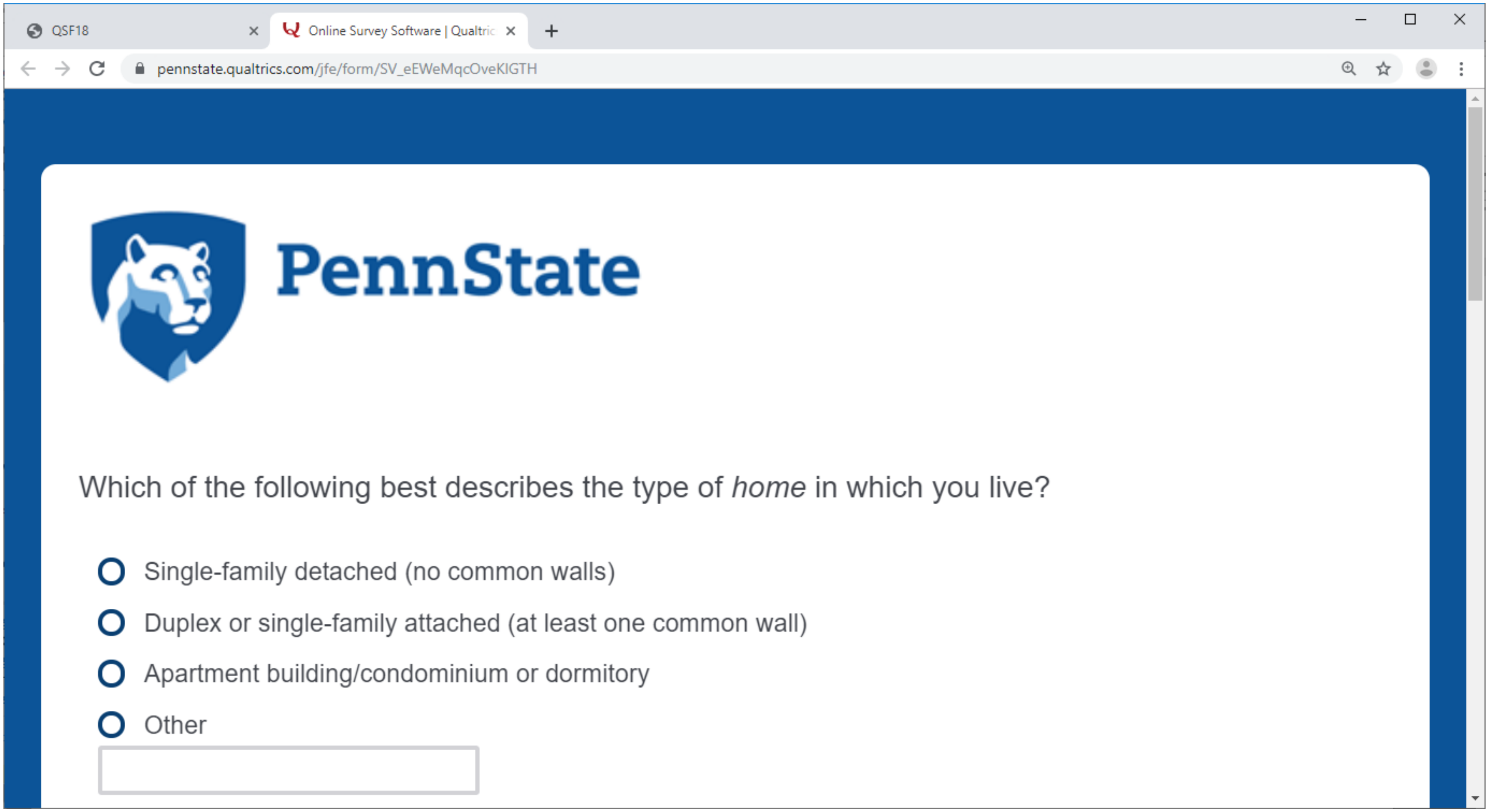
Self Assessment of Hearing Ability

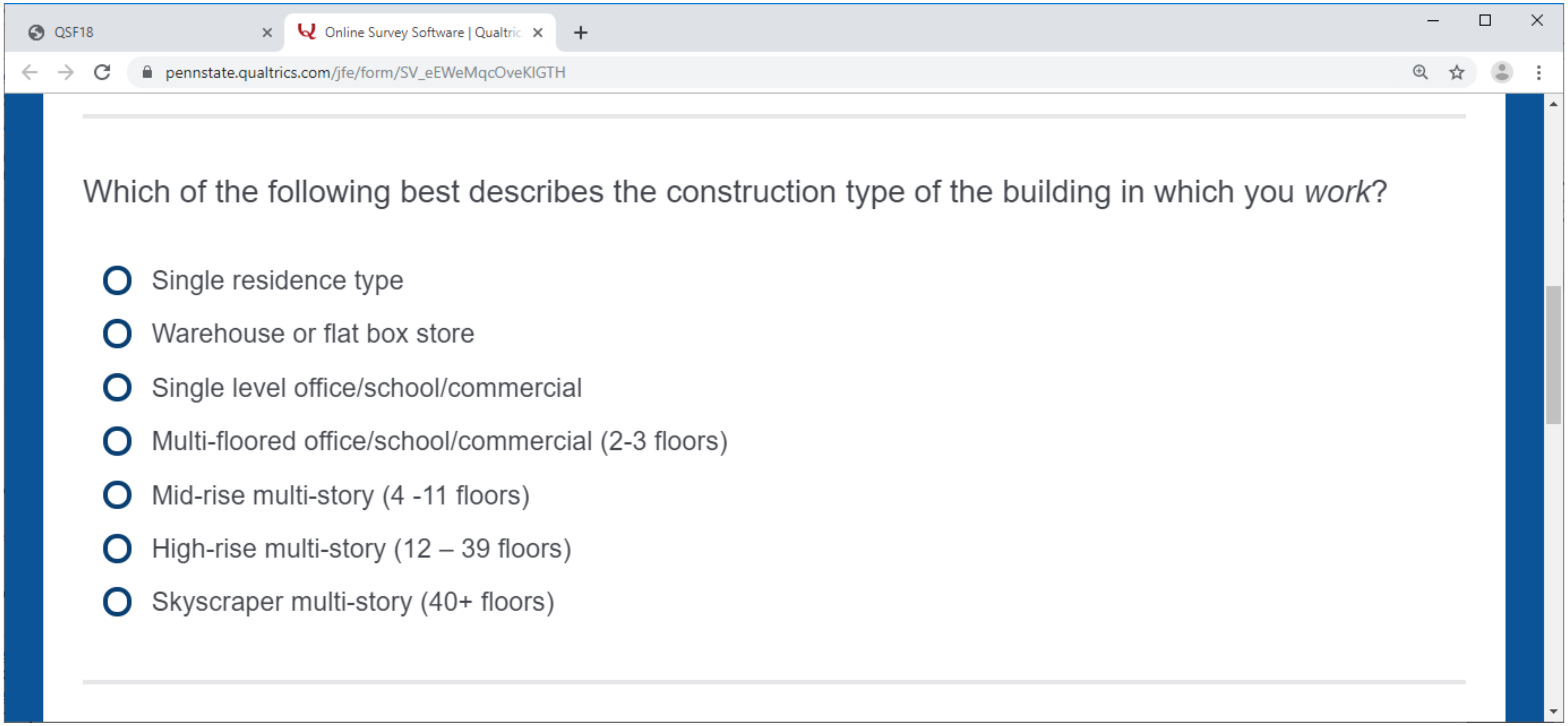


If answer to question about hearing is somewhat or severely diminished, then inquire about hearing aids:

For either answer to question about hearing, survey then proceeds to house construction and noise questions.

House Construction and Home Noise Environment





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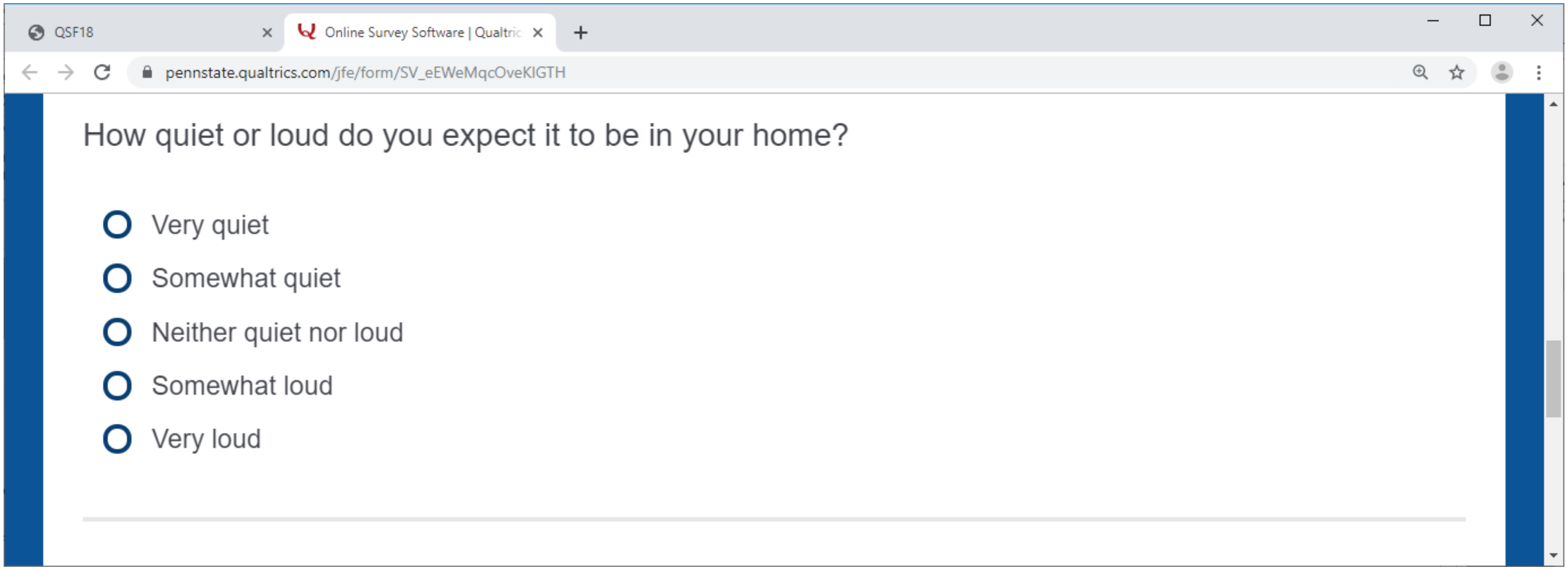
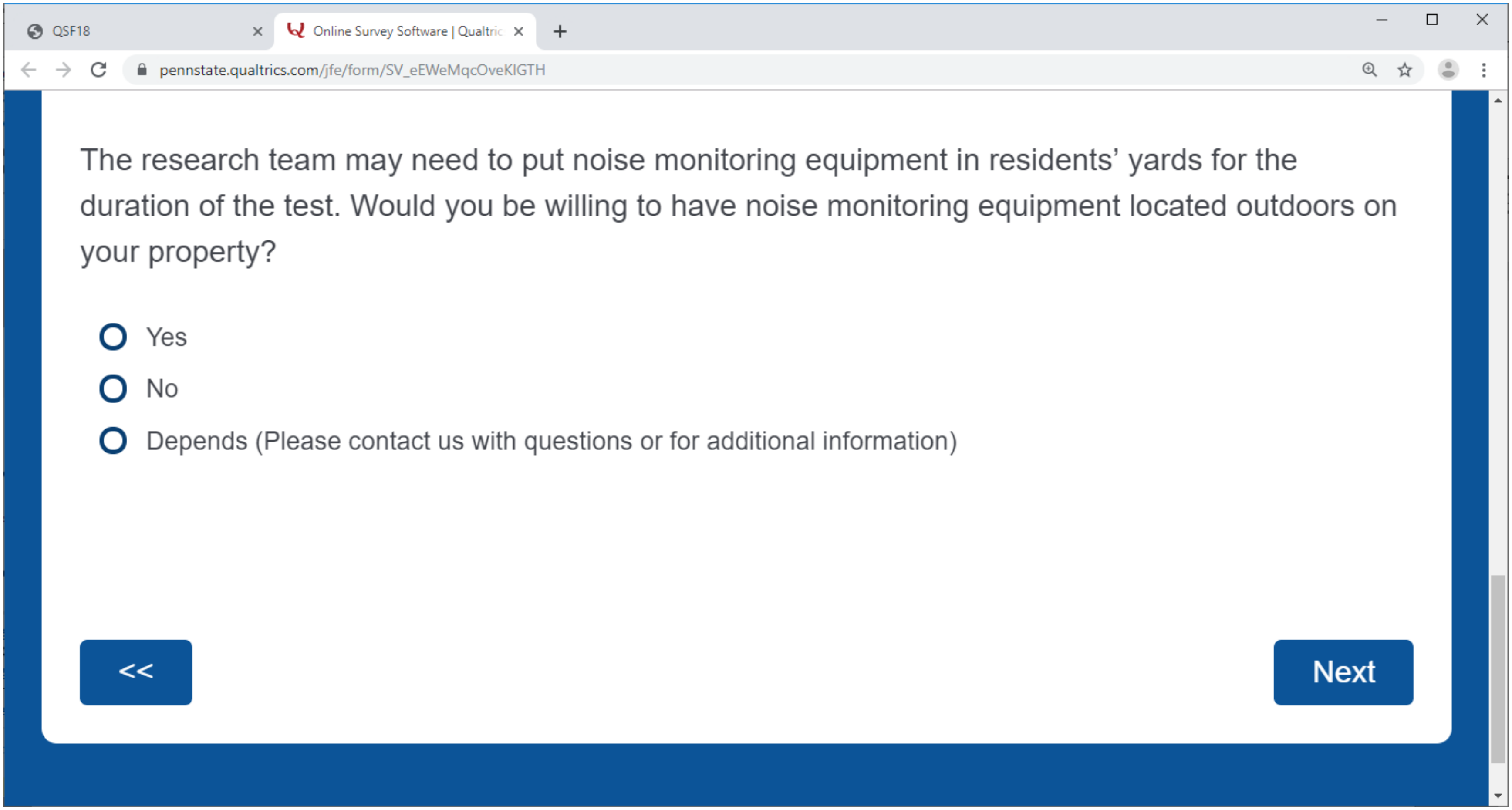
Which of the following best describes the construction type of the building in which you *work*?

- Single residence type
- Warehouse or flat box store
- Single level office/school/commercial
- Multi-floored office/school/commercial (2-3 floors)
- Mid-rise multi-story (4 -11 floors)
- High-rise multi-story (12 – 39 floors)
- Skyscraper multi-story (40+ floors)



How quiet or loud do you expect it to be in your home?

- Very quiet
- Somewhat quiet
- Neither quiet nor loud
- Somewhat loud
- Very loud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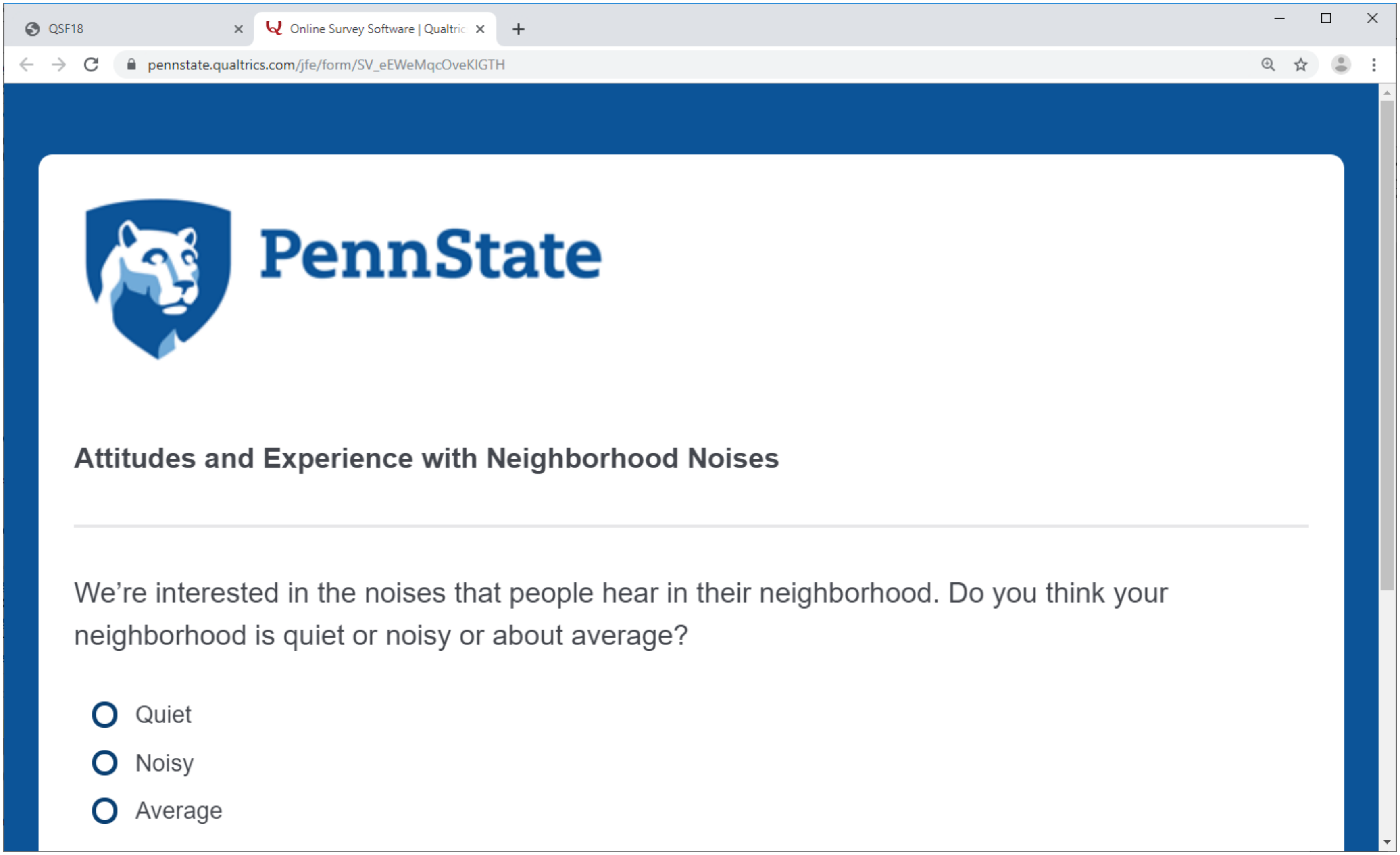
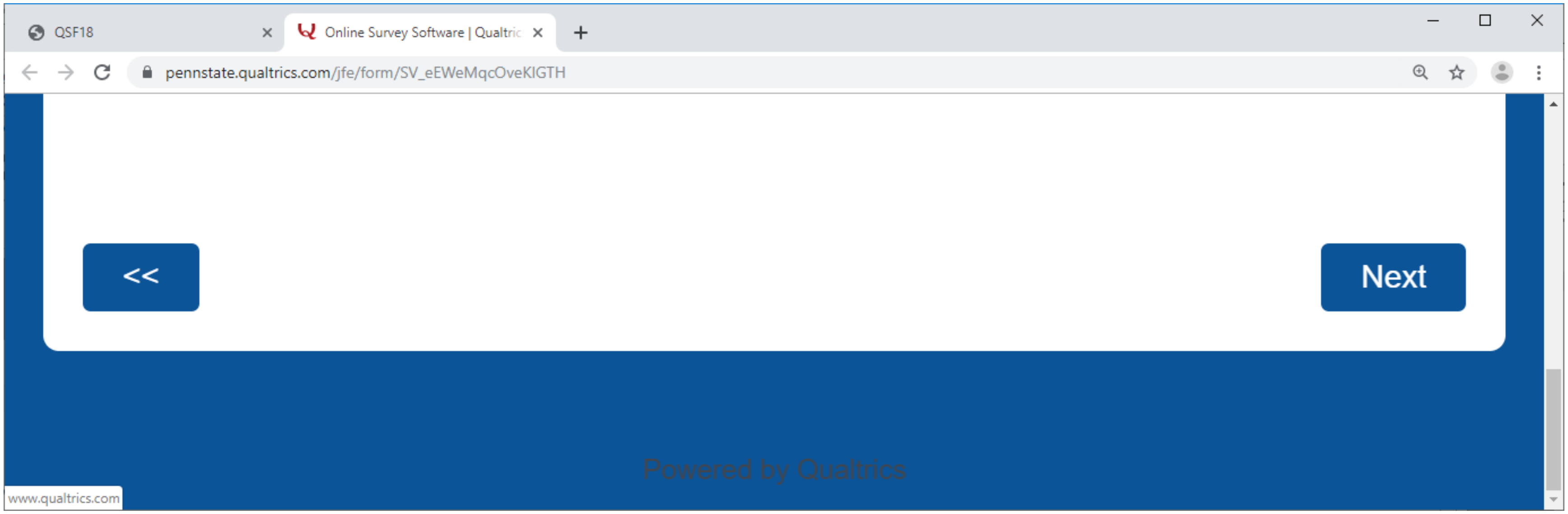
The research team may need to put noise monitoring equipment in residents' yards for the duration of the test. Would you be willing to have noise monitoring equipment located outdoors on your property?
Yes
No
Depends (Please contact us with questions or for additional information)
<<
Next

Attitudes and Experience with Neighborhood Noises

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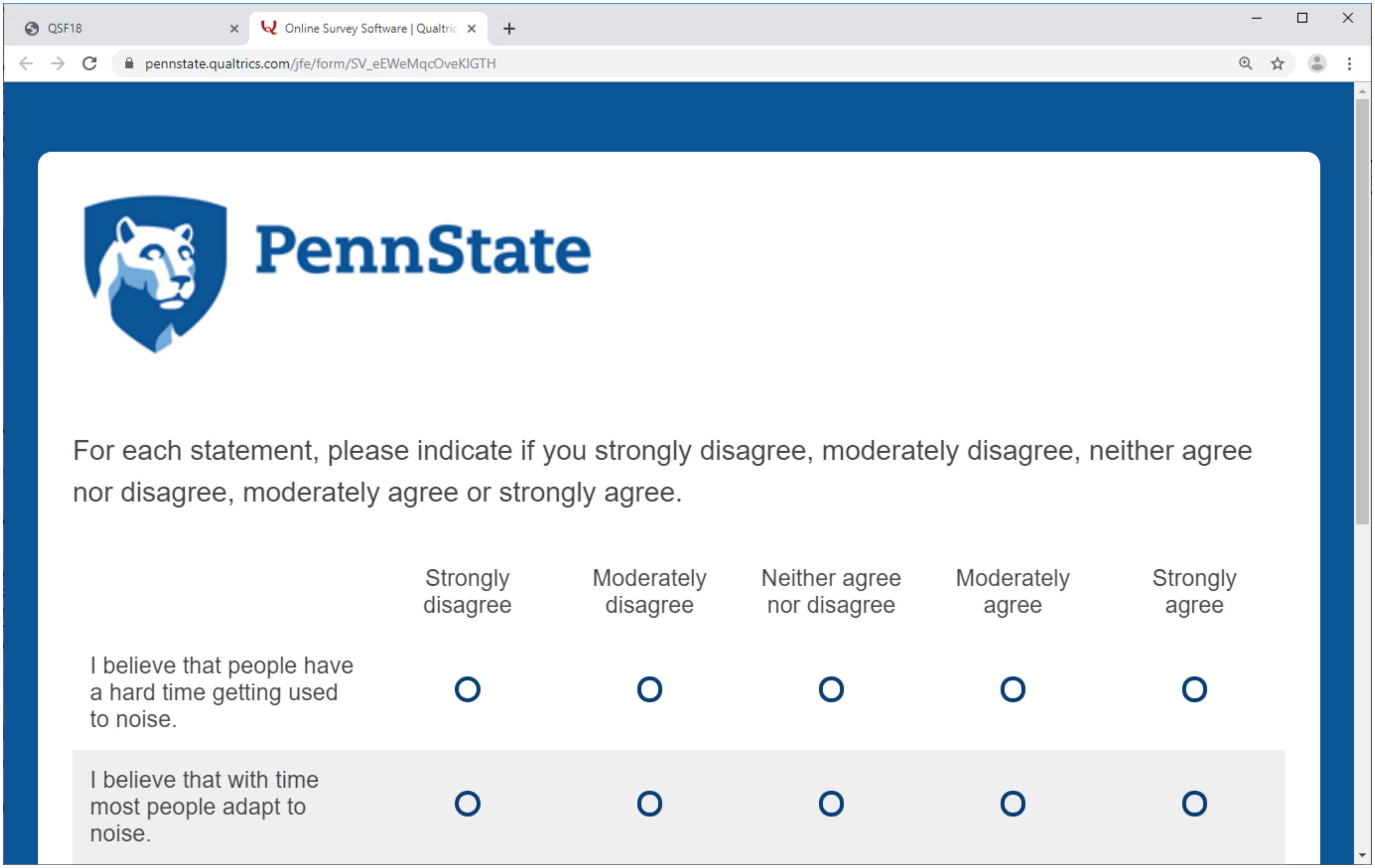

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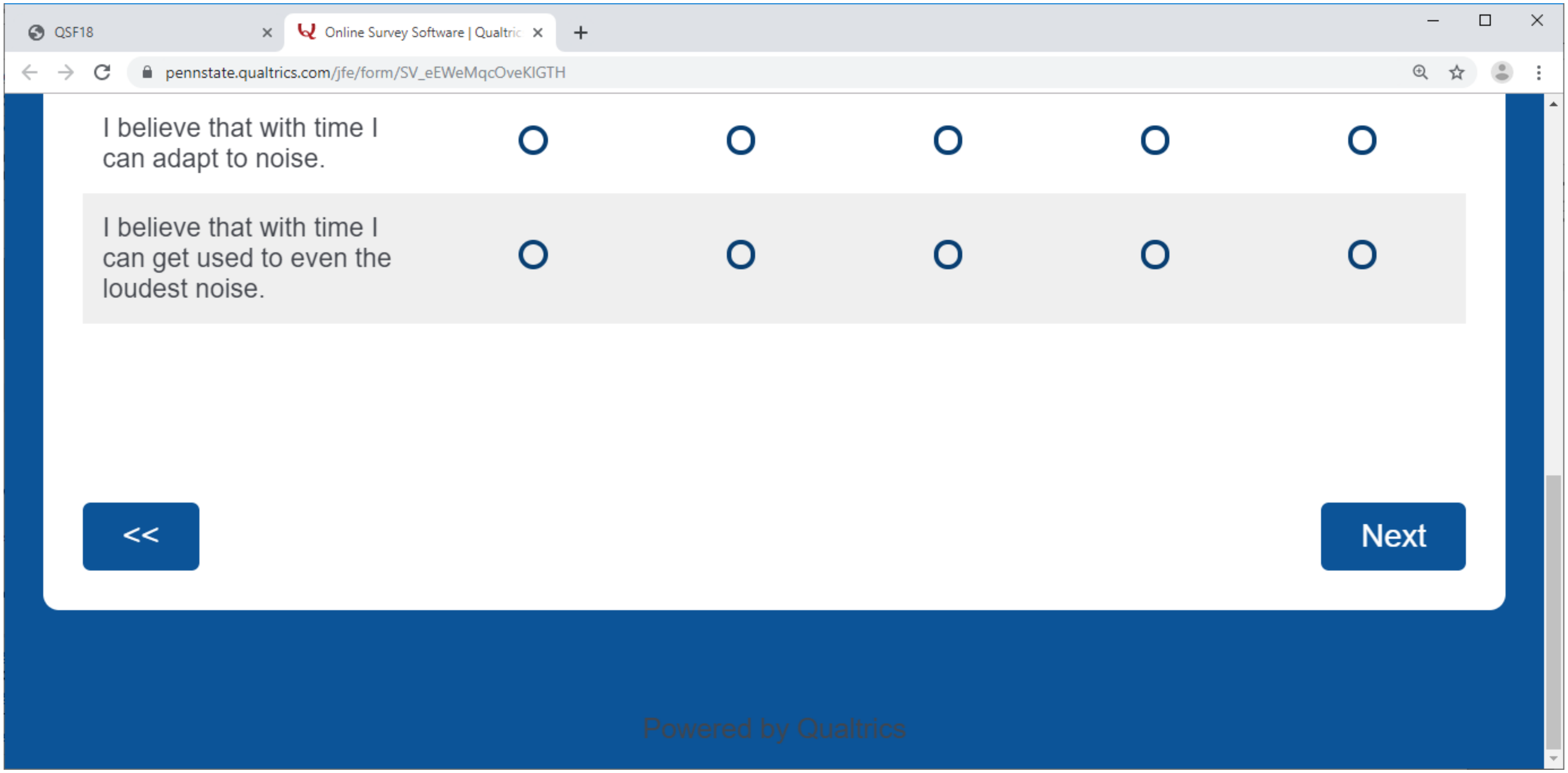
PennState

For each statement, please indicate if you strongly disagree, moderately disagree, neither agree nor disagree, moderately agree or strongly agree.

	Strongly disagree	Moderately disagree	Neither agree nor disagree	Moderately agree	Strongly agree
I believe that people have a hard time getting used to noise.	O	O	O	O	O
I believe that with time most people adapt to noise.	O	O	O	O	O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I believe that with time I can adapt to noise.
I believe that with time I can get used to even the loudest noise.
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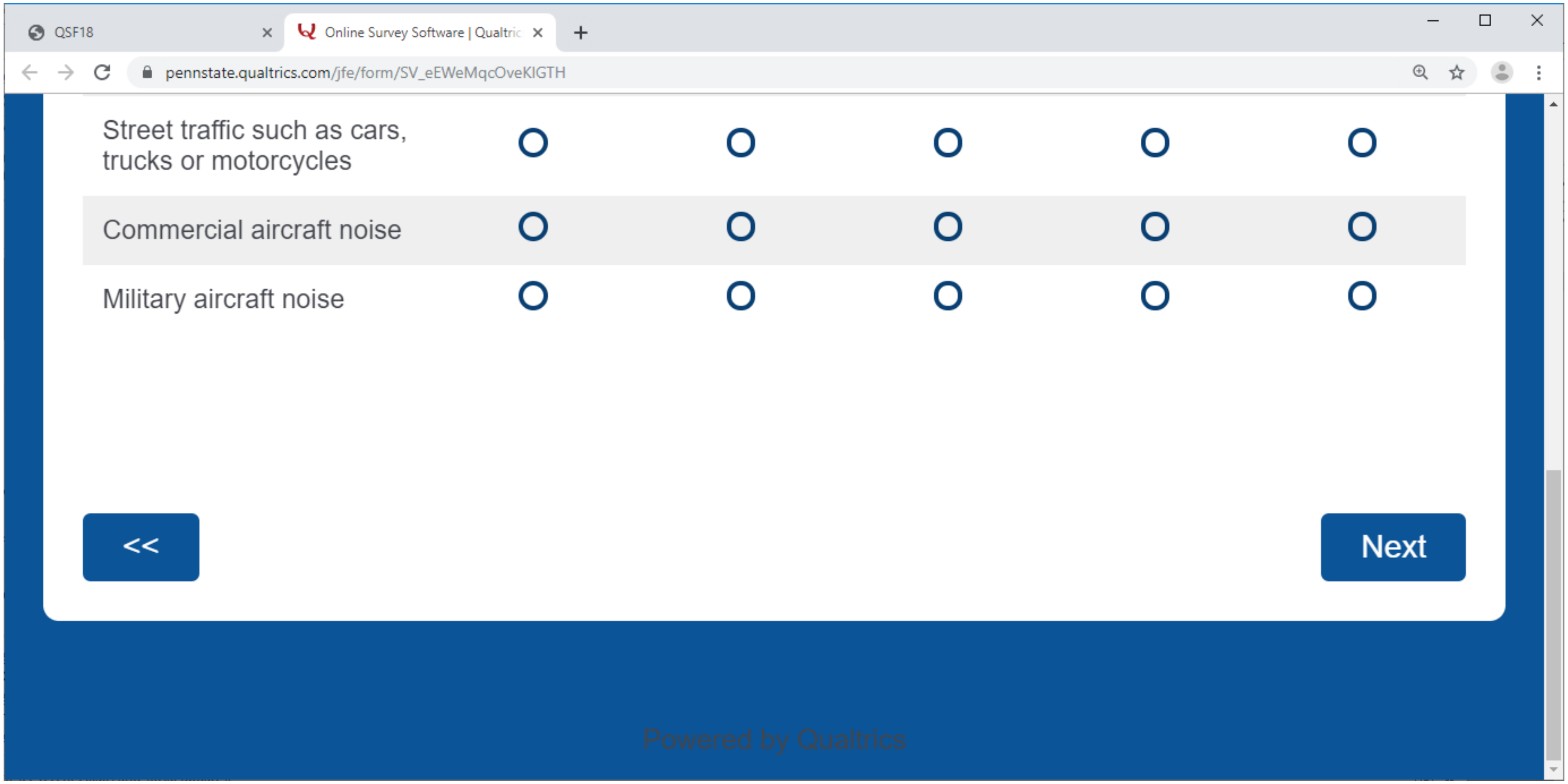
PennState

Next is a list of noises that might occur in your neighborhood. Please indicate how much each noise bothers, disturbs or annoys you. When you are at home, how much does noise from the indicated noise source bother, disturb, or annoy you?

	Not heard/ Not at all annoyed	Slightly annoyed	Moderately annoyed	Very Annoyed	Extremely annoyed
Barking dogs	O	O	O	O	O
Thunder	O	O	O	O	O



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Street traffic such as cars, trucks or motorcycles
Commercial aircraft noise
Military aircraft noise
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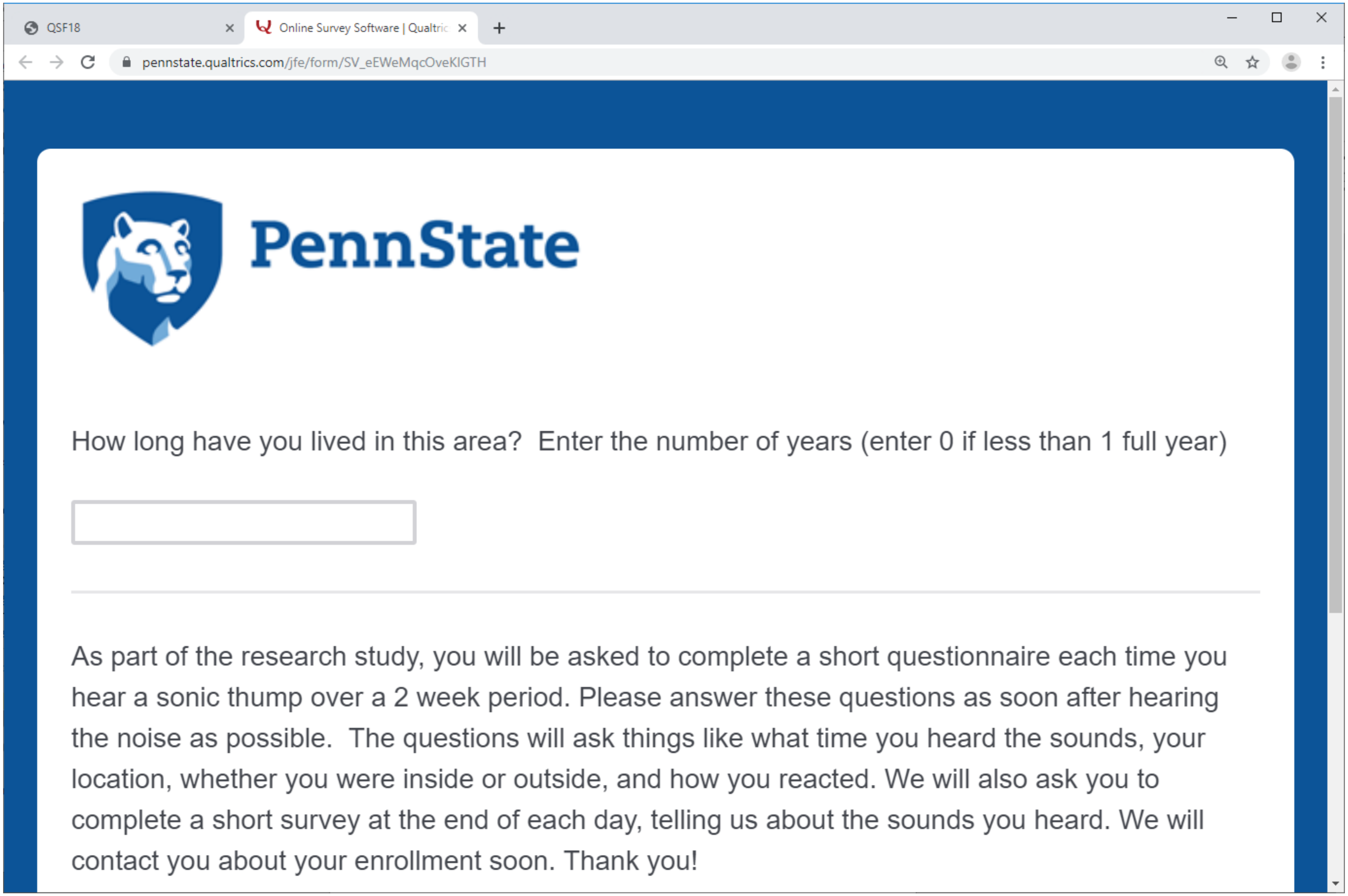
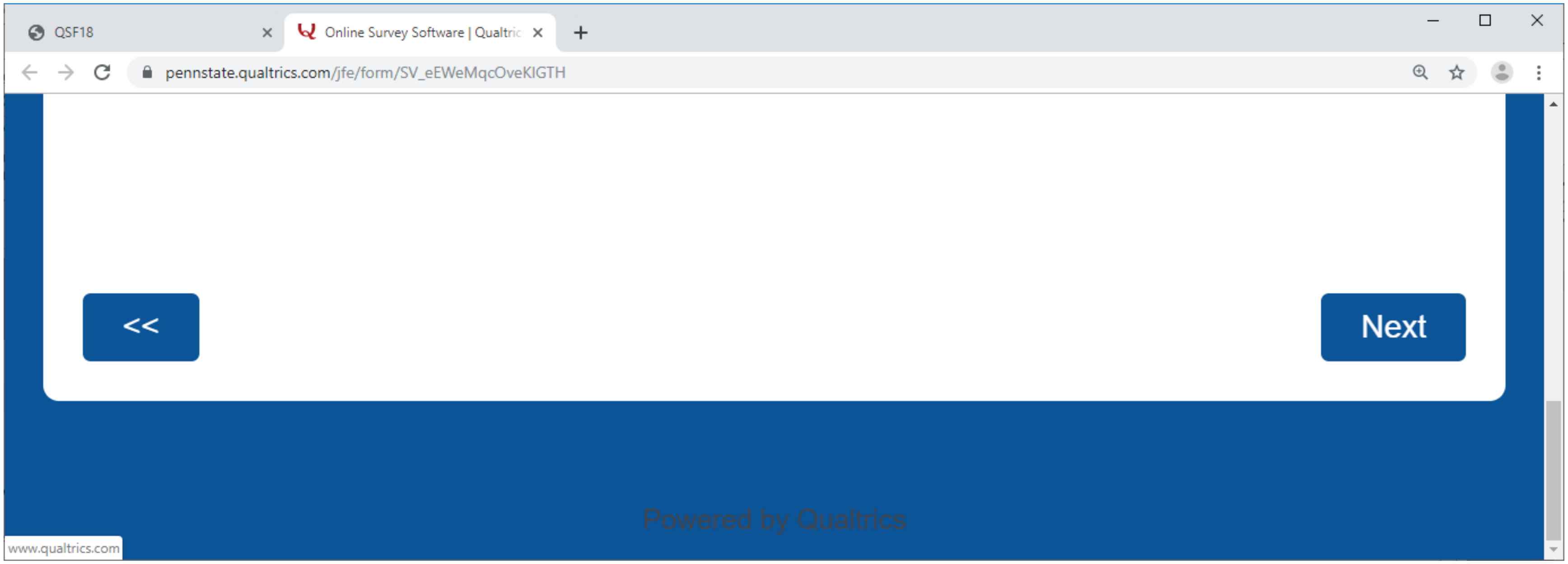
Length of Time in Current Home; Single Event and Daily Summary Instructions



How long have you lived in this area? Enter the number of years (enter 0 if less than 1 full year)

As part of the research study, you will be asked to complete a short questionnaire each time you hear a sonic thump over a 2 week period. Please answer these questions as soon after hearing the noise as possible. The questions will ask things like what time you heard the sounds, your location, whether you were inside or outside, and how you reacted. We will also ask you to complete a short survey at the end of each day, telling us about the sounds you heard. We will contact you about your enrollment soon. Thank you!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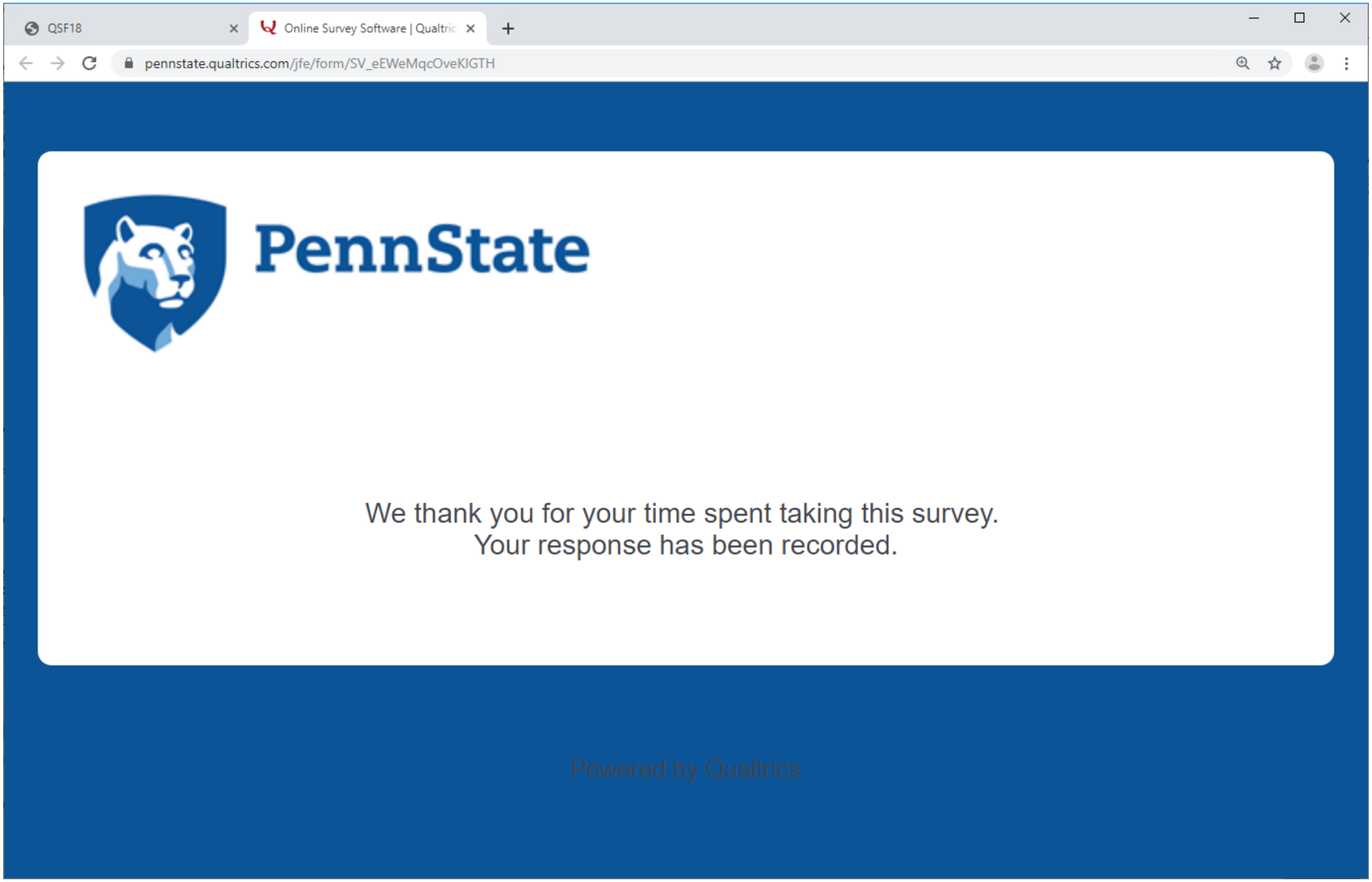
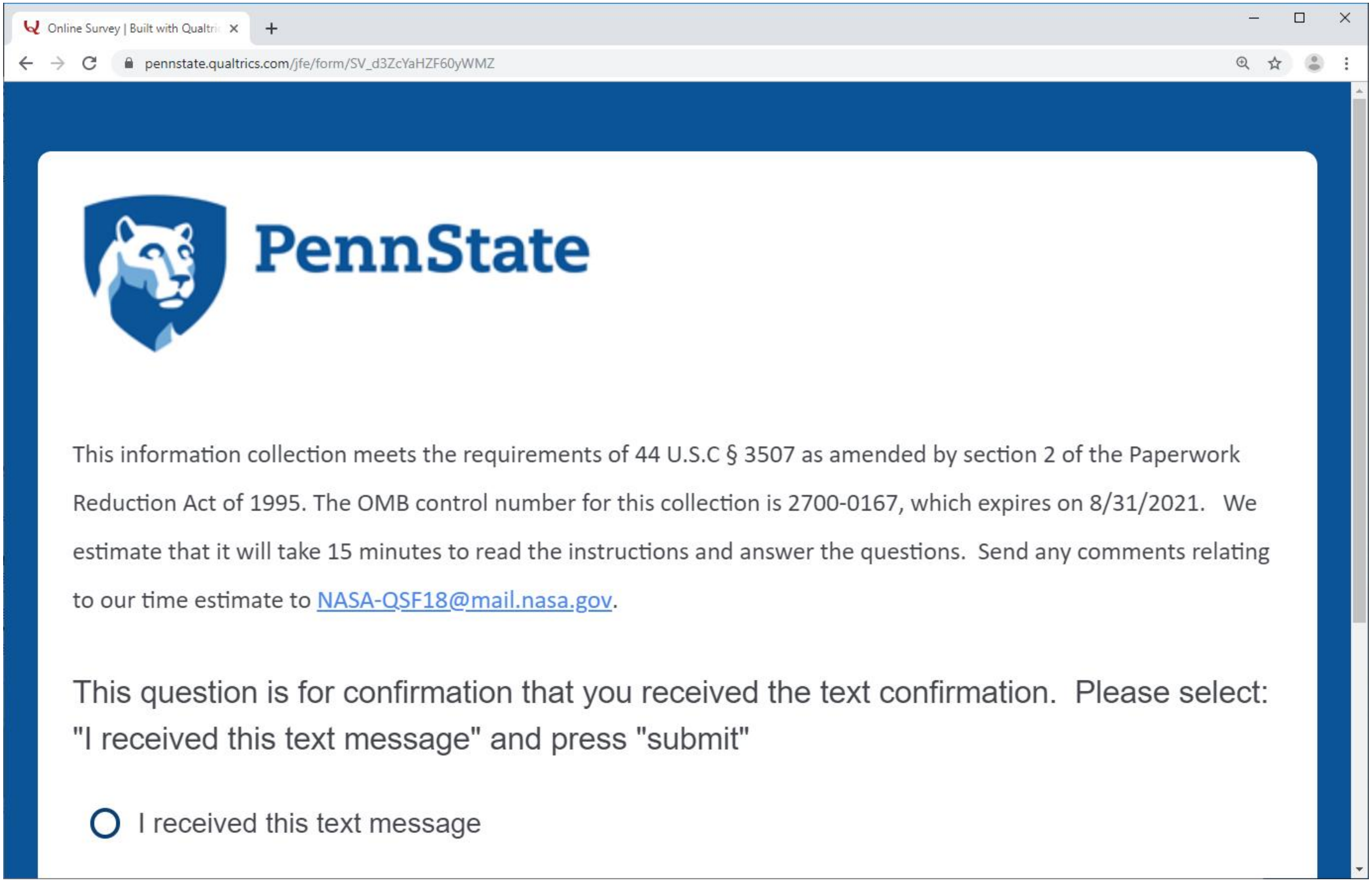
End of Background Survey Thank You



Enrollment Text Message

Qualtrics generated a unique link for each respondent. The text message read: You recently volunteered for a NASA sponsored study. You are in the text message group, so please click the link to verify: (Qualtrics generated small link).

Receipt of Text Confirmation



Online Survey | Built with Qualtrics

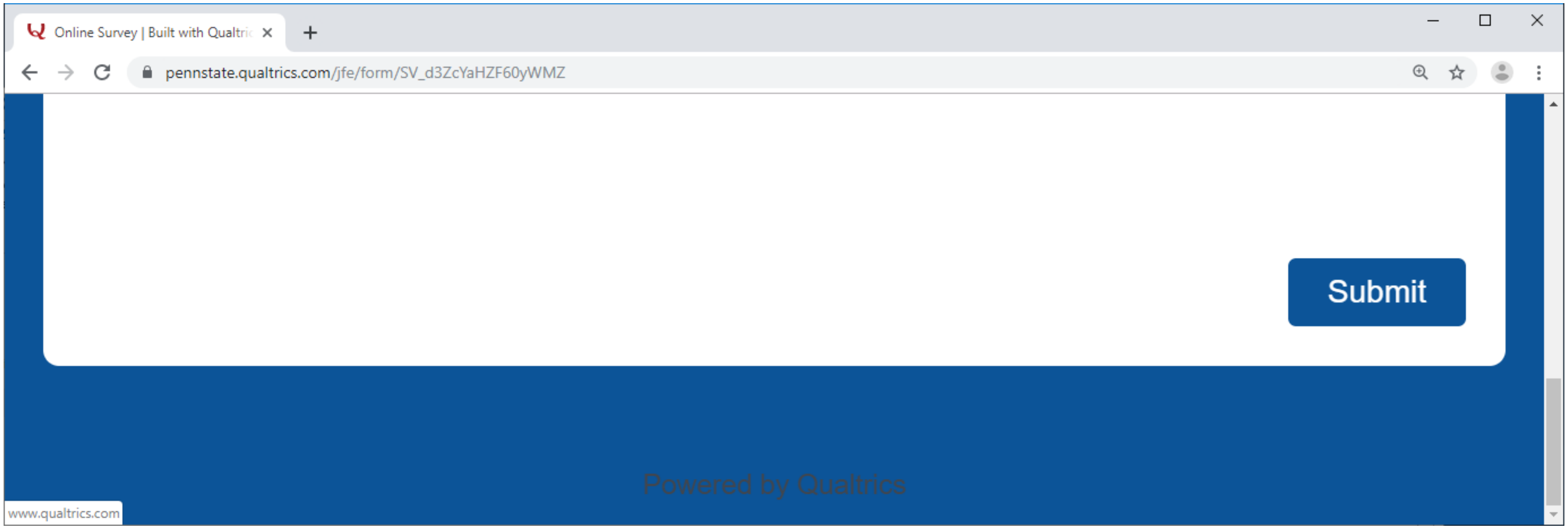
pennstate.qualtrics.com/jfe/form/SV_d3ZcYaHZF60yWMZ

PennState

This information collection meets the requirements of 44 U.S.C § 3507 as amended by section 2 of the Paperwork Reduction Act of 1995. The OMB control number for this collection is 2700-0167, which expires on 8/31/2021. We estimate that it will take 15 minutes to read the instructions and answer the questions. Send any comments relating to our time estimate to NASA-QSF18@mail.nasa.gov.

This question is for confirmation that you received the text confirmation. Please select: "I received this text message" and press "submit"

○ I received this text message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pennstate.qualtrics.com/jfe/form/SV_d3ZcYaHZF60yWMZ
Submit
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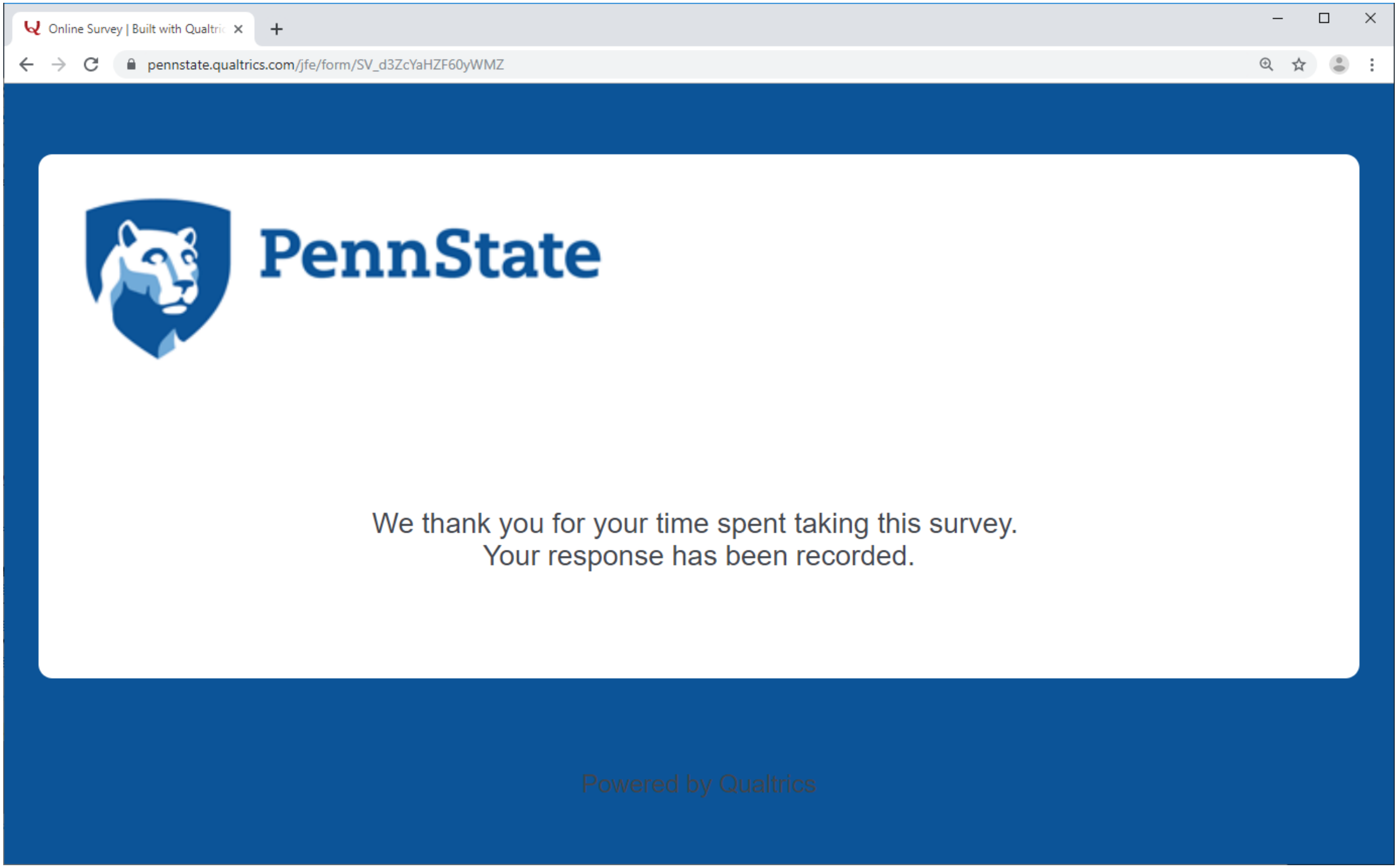
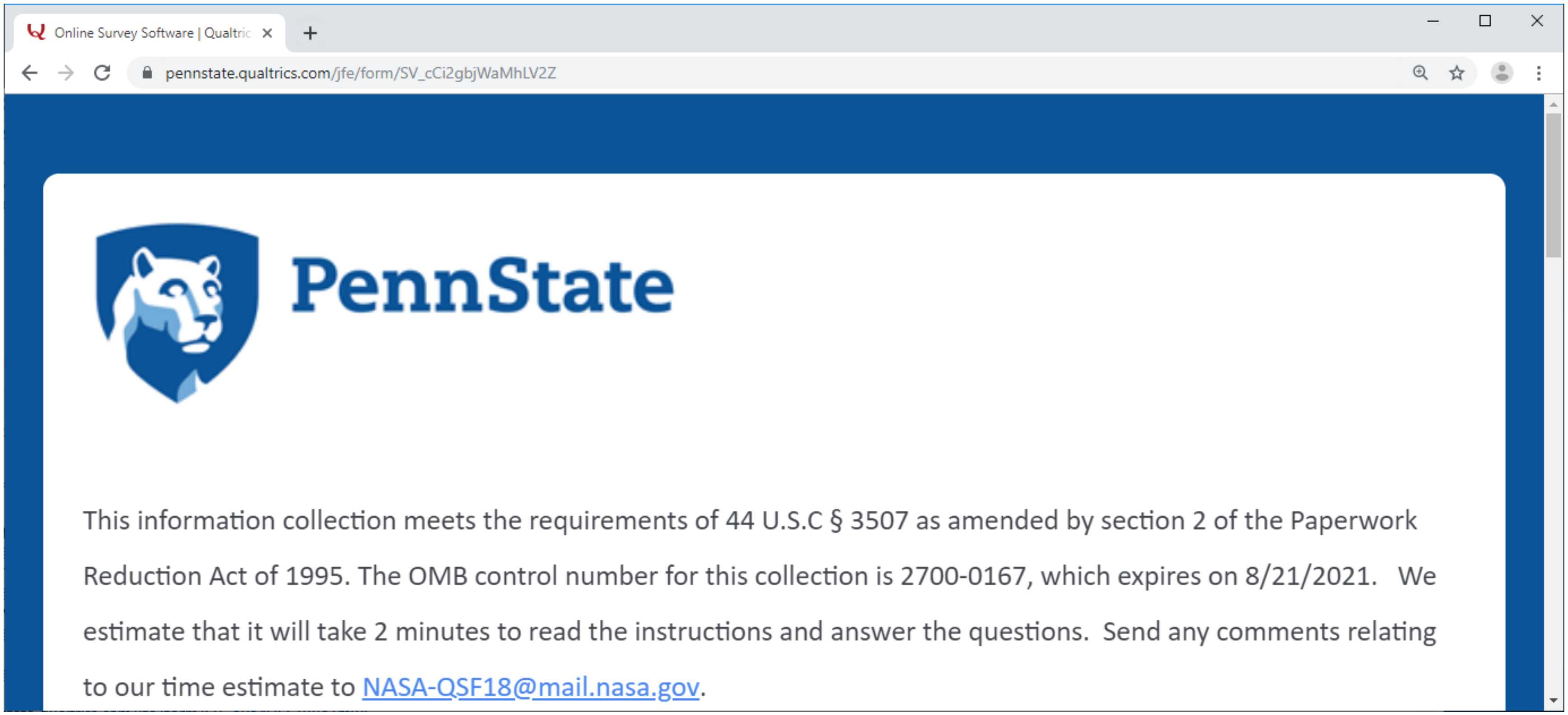
Text Confirmation Thank You



QSF18 Single Event

Note: The survey was not openly available online. Each participant received a unique link so that only those who were enrolled could complete the surveys. All surveys were timed stamped, both start and finish.

Date and Time of Sonic Thump



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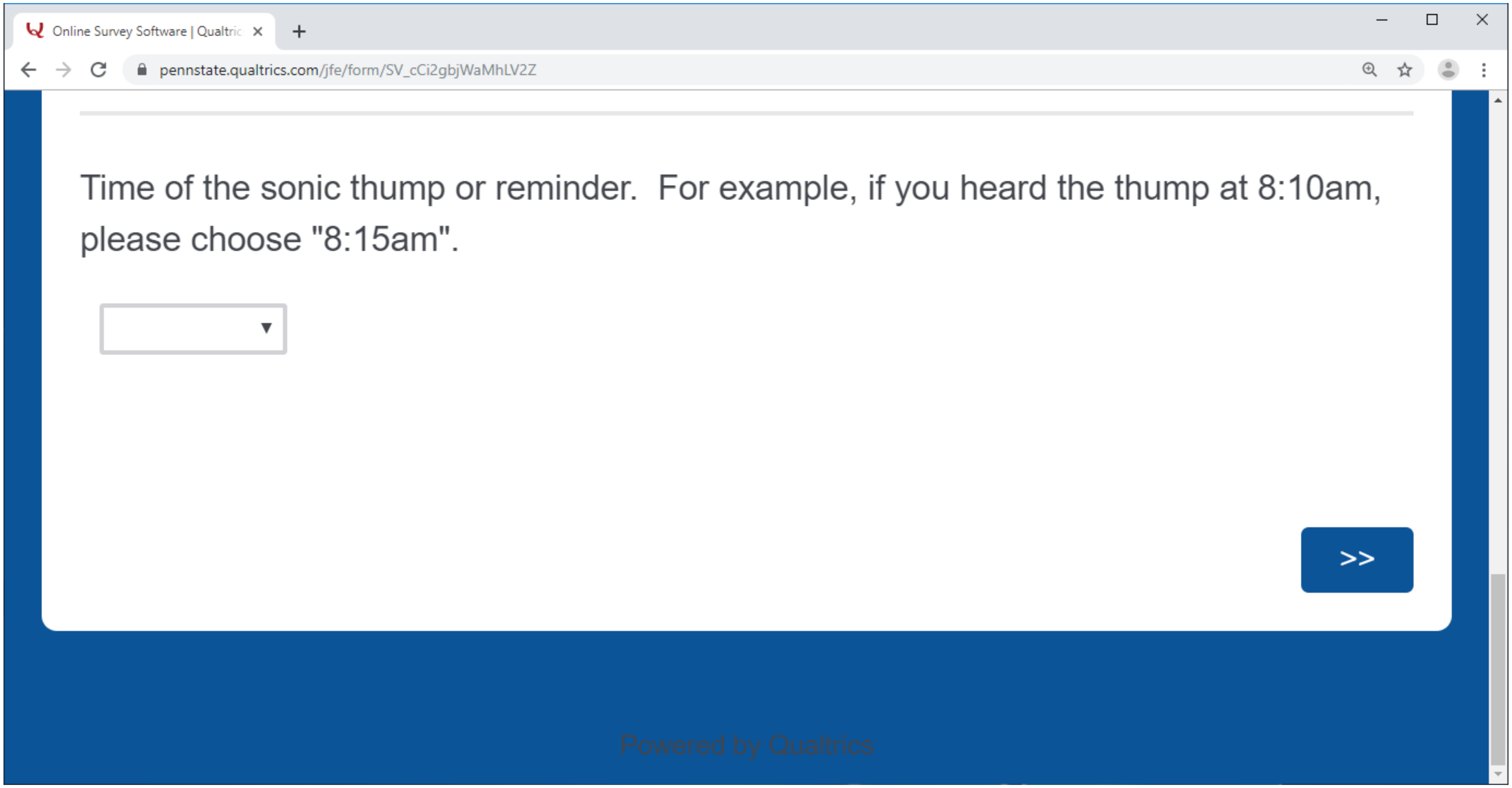
pennstate.qualtrics.com/jfe/form/SV_cCi2gbjWaMhLV2Z

Quiet Supersonic Flights 2018

Single Event Response Form

Date of the sonic thump or reminder.

- Monday, November 5
- Tuesday, November 6
- Wednesday, November 7
- Thursday, November 8
- Friday, November 9
- Saturday, November 10
- Sunday, November 11
- Monday, November 12
- Tuesday, November 13
- Wednesday, November 14
- Thursday, November 15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Time of the sonic thump or reminder. For example, if you heard the thump at 8:10am, please choose "8:15am".
>>
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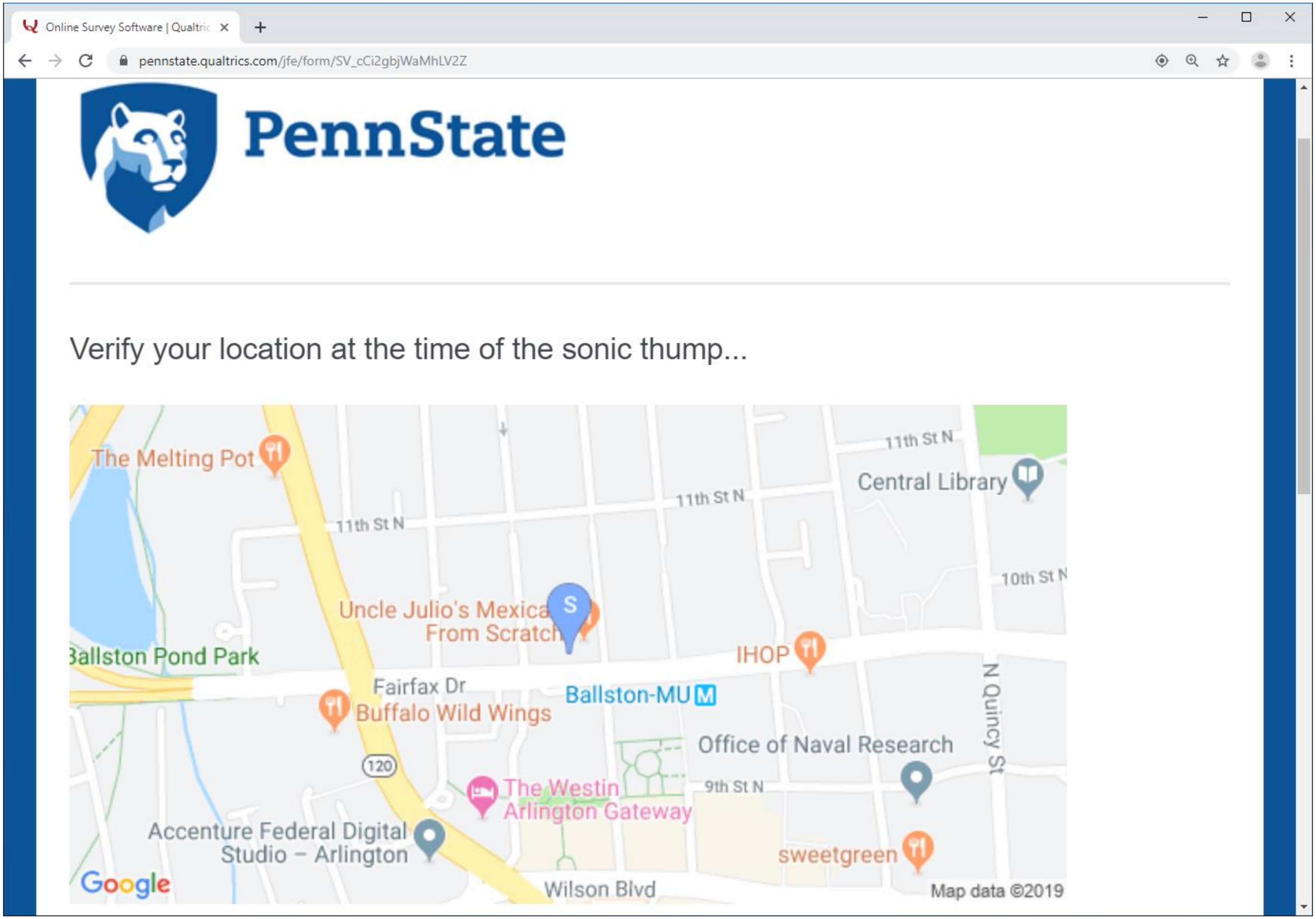
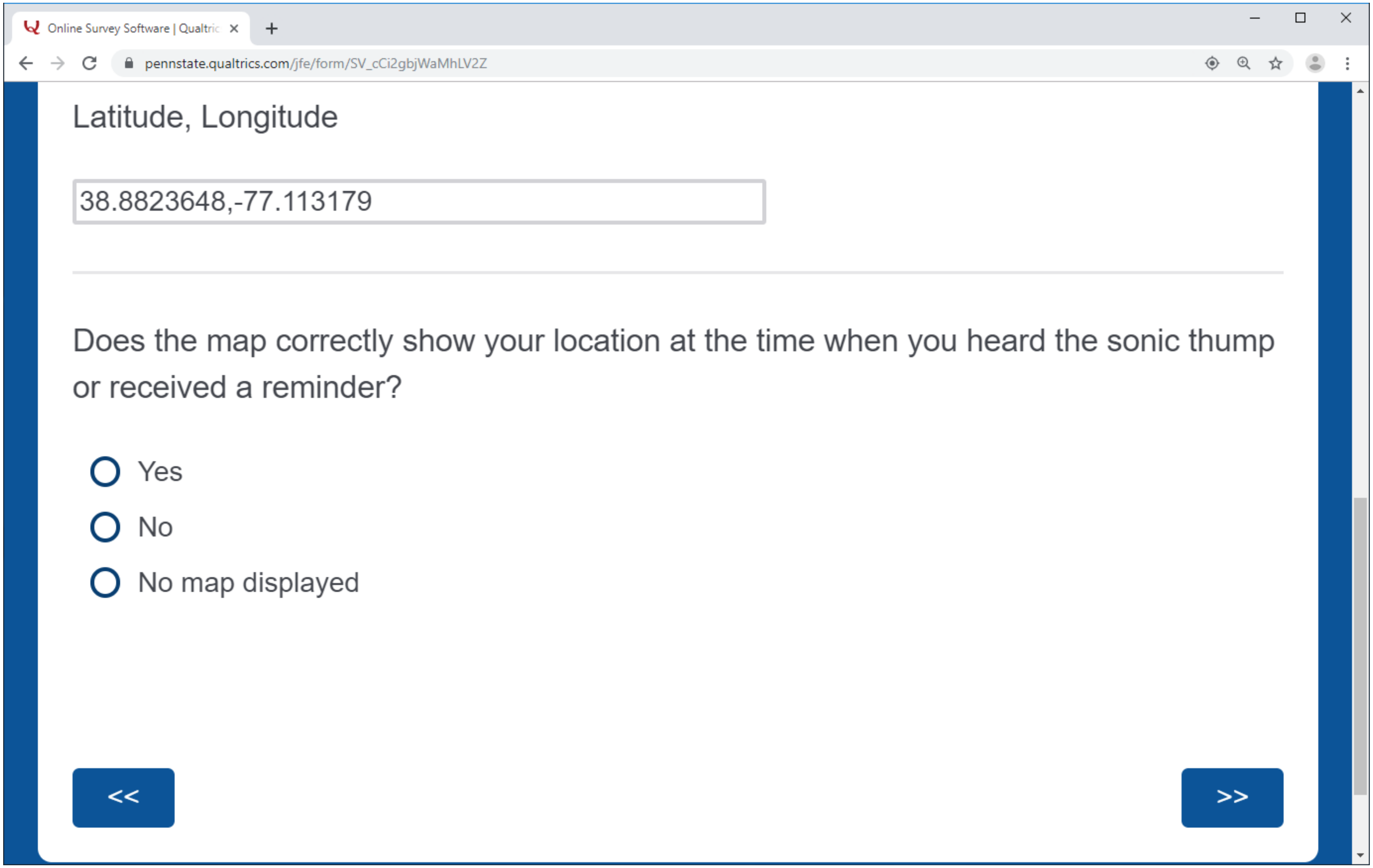
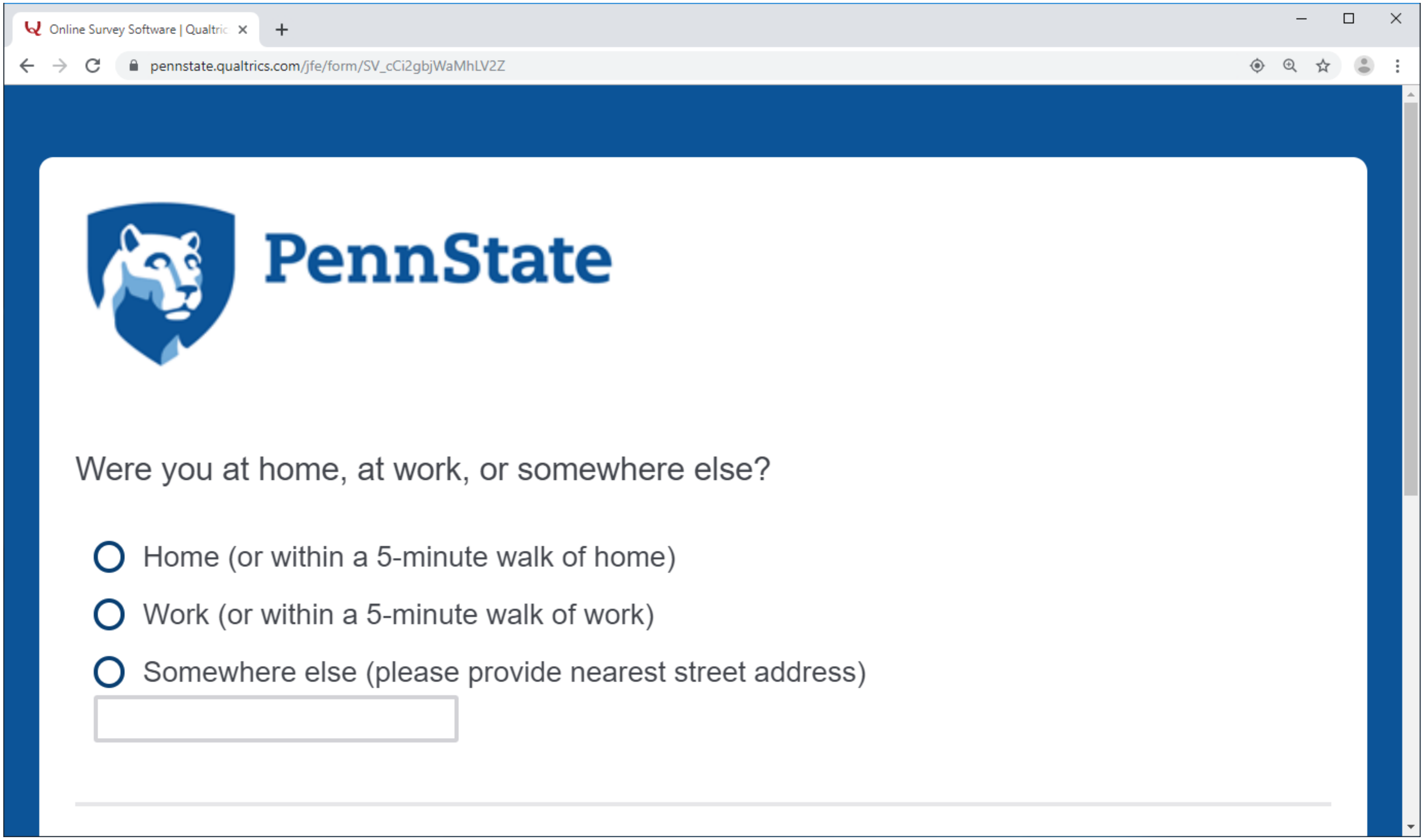
Location Verification with Sonic Thump Inquiry


Online Survey Software | Qualtric
pennstate.qualtrics.com/jfe/form/SV_cCi2gbjWaMhLV2Z
PennState
Verify your location at the time of the sonic thump...
The Melting Pot
11th St N
11th St N
11th St N
Central Library
10th St N
Uncle Julio's Mexica
From Scratch
Ballston Pond Park
IHOP
Fairfax Dr
Buffalo Wild Wings
Ballston-MU
N Quincy St
Office of Naval Research
120
9th St N
The Westin
Arlington Gateway
Accenture Federal Digital
Studio – Arlington
sweetgreen
Google
Wilson Blvd
Map data ©2019



If the answer is no or no map displayed is No, then survey asks whether at home, work, or another location, then if a sonic thump was heard:



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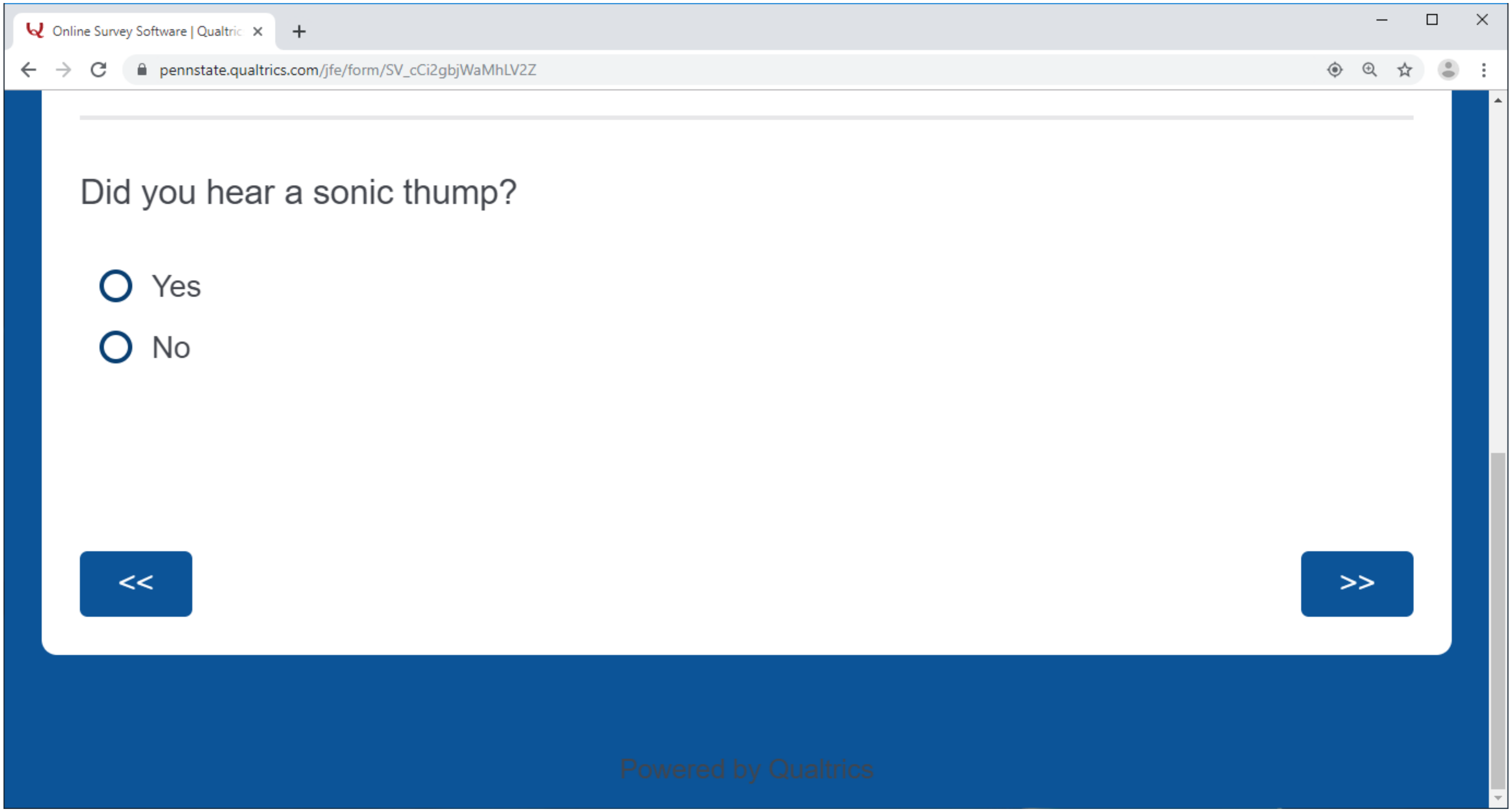
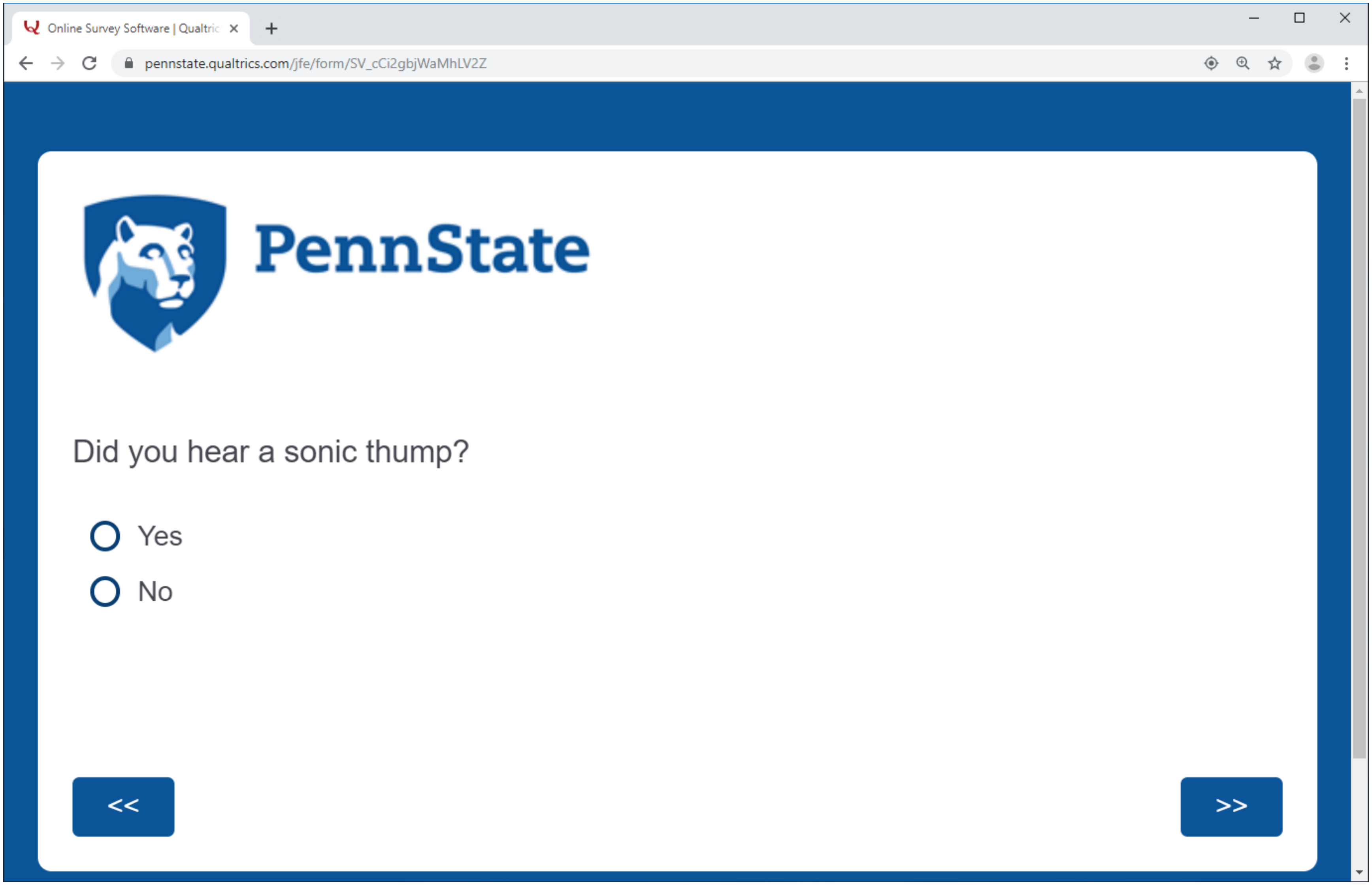
PennState

Were you at home, at work, or somewhere else?

- Home (or within a 5-minute walk of home)
- Work (or within a 5-minute walk of work)
- Somewhere else (please provide nearest street address)


Online Survey Software | Qualtric
pennstate.qualtrics.com/jfe/form/SV_cCi2gbjWaMhLV2Z
Did you hear a sonic thump?
Yes
No
<<
>>
Powered by Qualtrics

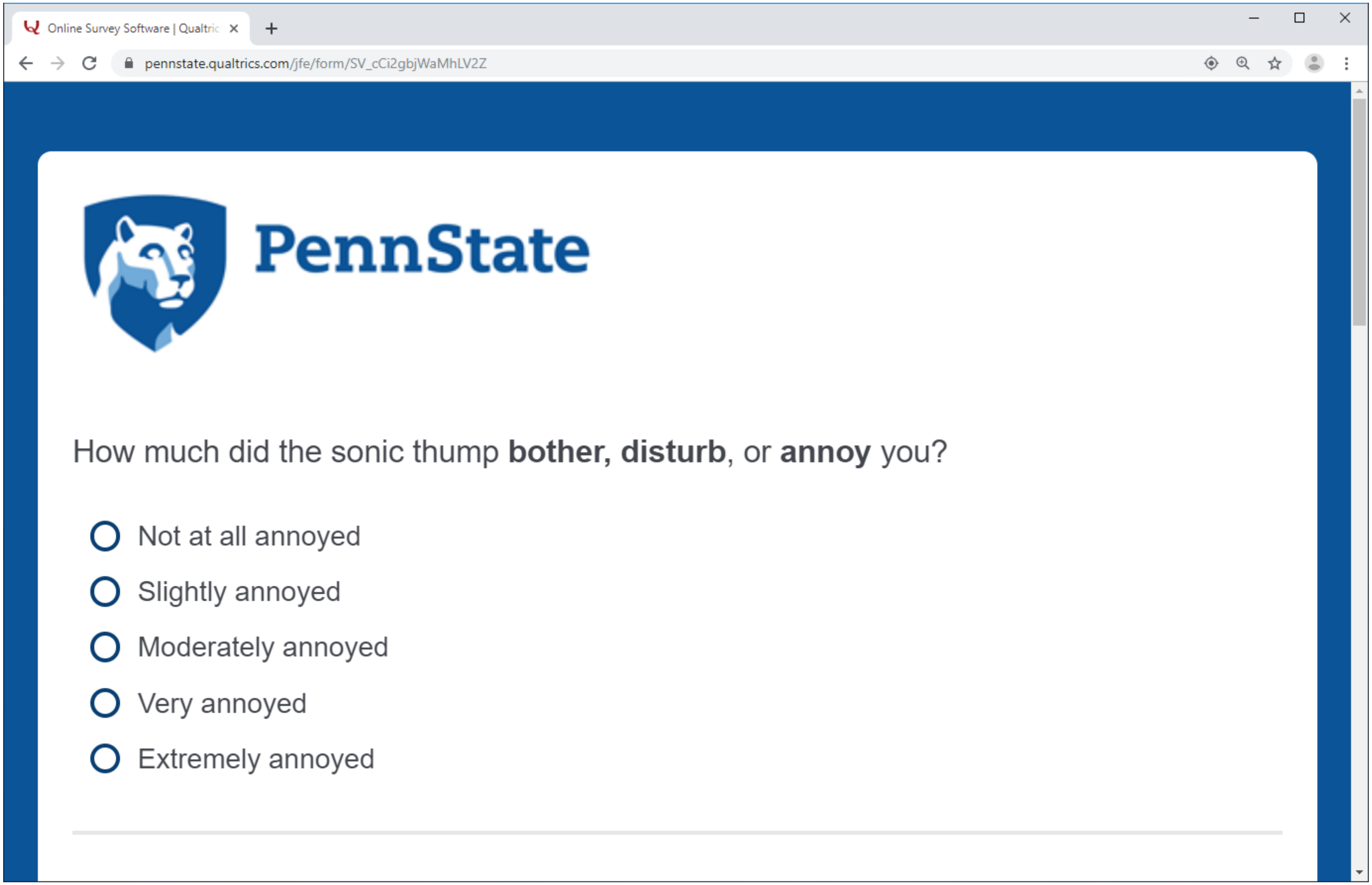
If the answer to did the map correctly show your location is yes, then survey proceeds directly to asking if a sonic thump was heard:



If the answer to did you hear a sonic thump is No, then survey skips questions about annoyance and response and proceeds to questions about the environment.

If the answer to did you hear a sonic thump is Yes, then survey proceeds to questions about annoyance and response.

Annoyance and Perceptual Response Questions



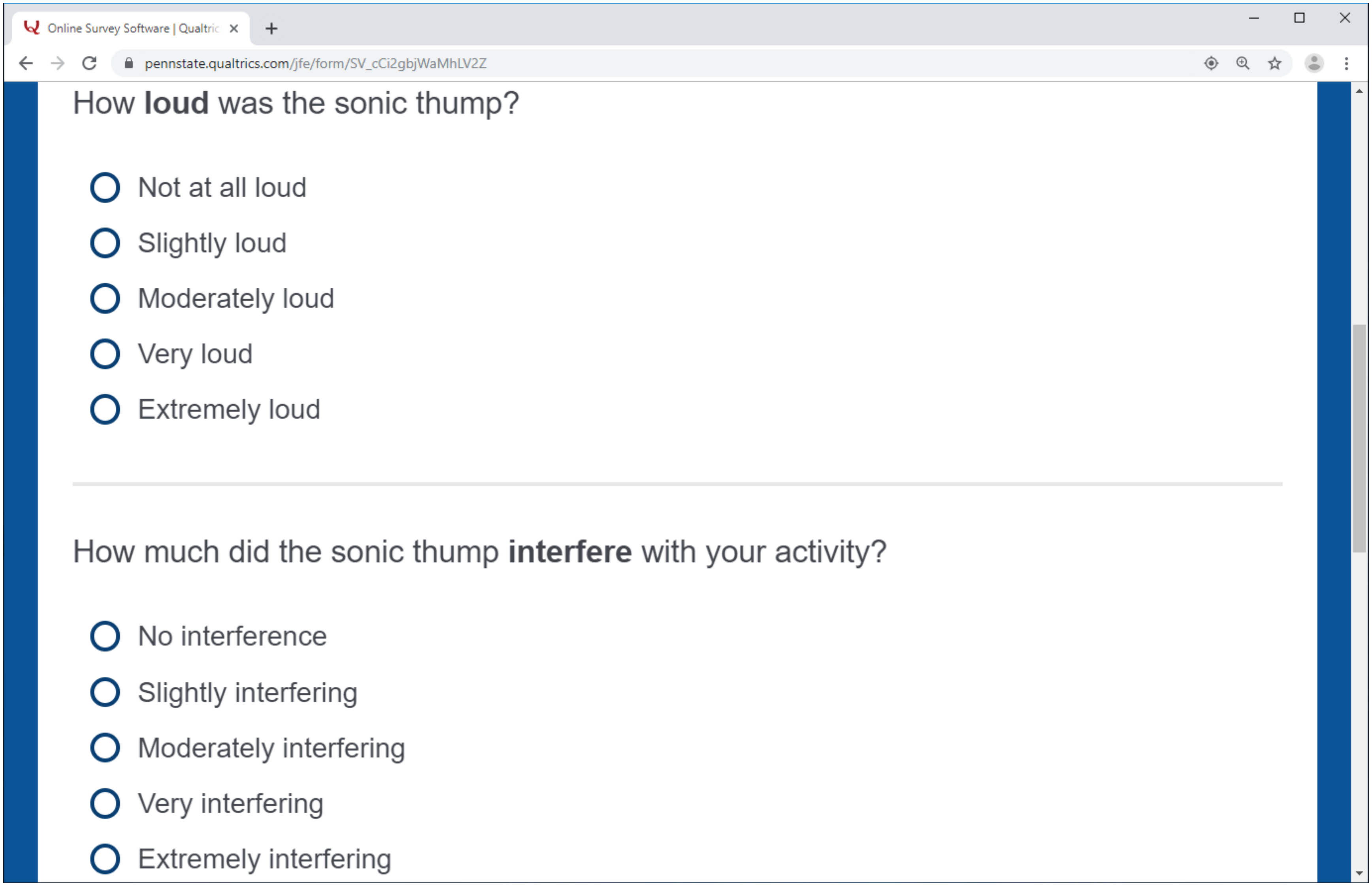
Online Survey Software | Qualtric

pennstate.qualtrics.com/jfe/form/SV_cCi2gbjWaMhLV2Z

PennState

How much did the sonic thump **bother, disturb**, or **annoy** you?

- Not at all annoyed
- Slightly annoyed
- Moderately annoyed
- Very annoyed
- Extremely annoyed


Online Survey Software | Qualtric

pennstate.qualtrics.com/jfe/form/SV_cCi2gbjWaMhLV2Z

How **loud** was the sonic thump?

- Not at all loud
- Slightly loud
- Moderately loud
- Very loud
- Extremely loud

How much did the sonic thump **interfere** with your activity?

- No interference
- Slightly interfering
- Moderately interfering
- Very interfering
- Extremely interfering

Online Survey Software | Qualtric

pennstate.qualtrics.com/jfe/form/SV_cCi2gbjWaMhLV2Z

Vibration is a motion. The motion may be seen, felt or heard. **Rattle** is a type of noise that can occur when objects move due to a vibration.

Did you see, hear, or feel **vibration** or **rattle**?

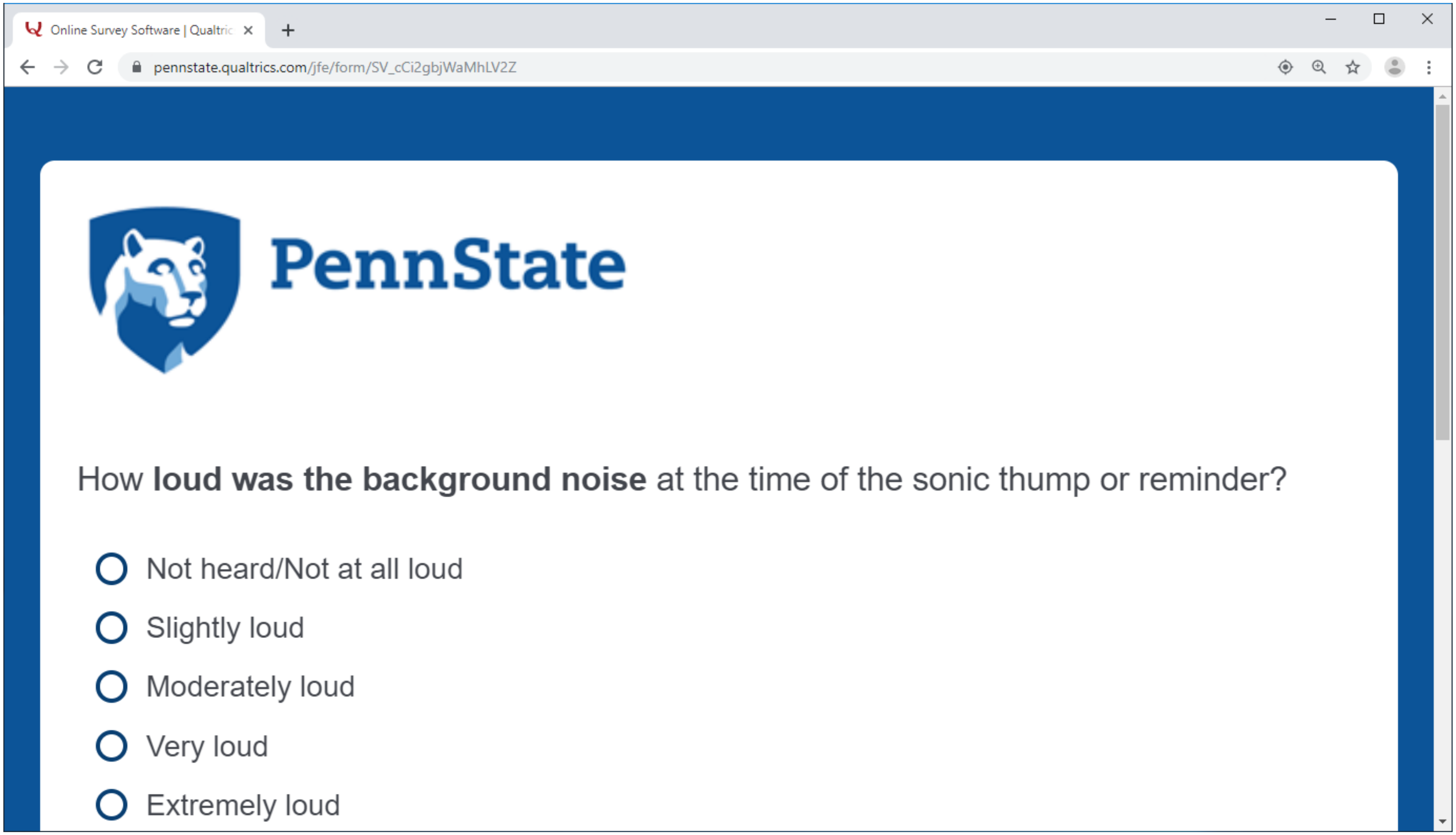
- Yes
- No

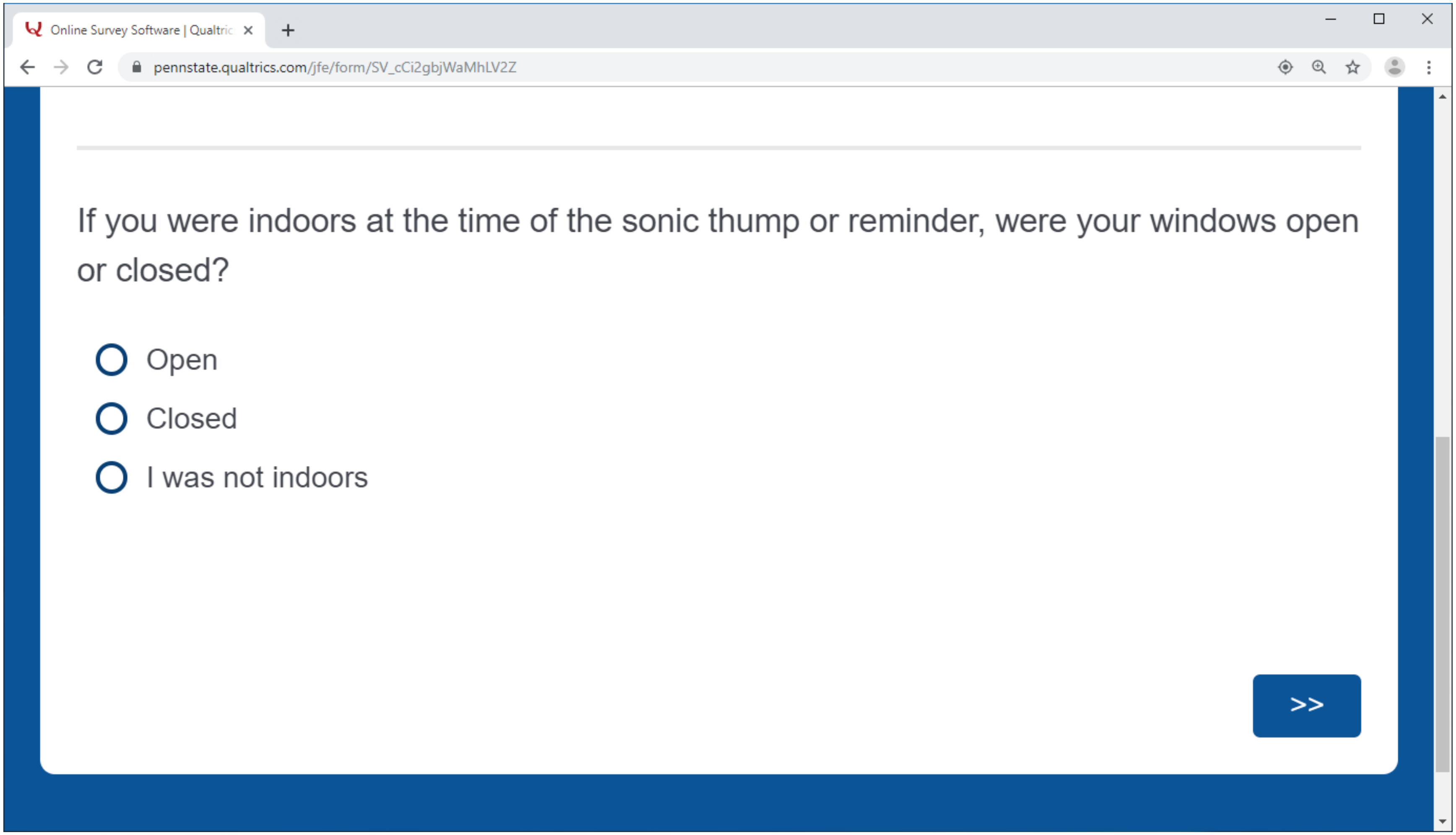
Did the sonic thump **startle** you?

- Yes
- No

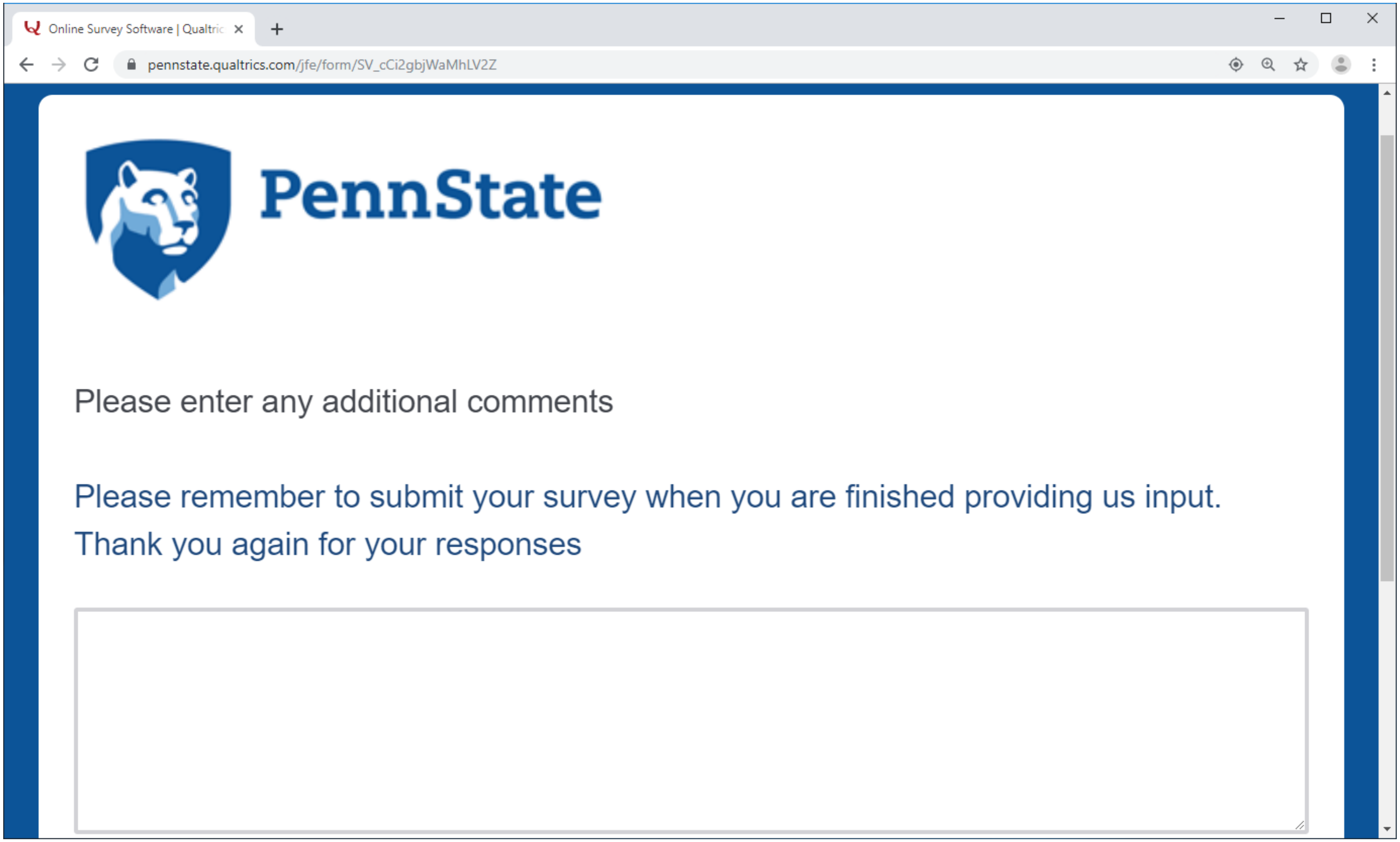
>>

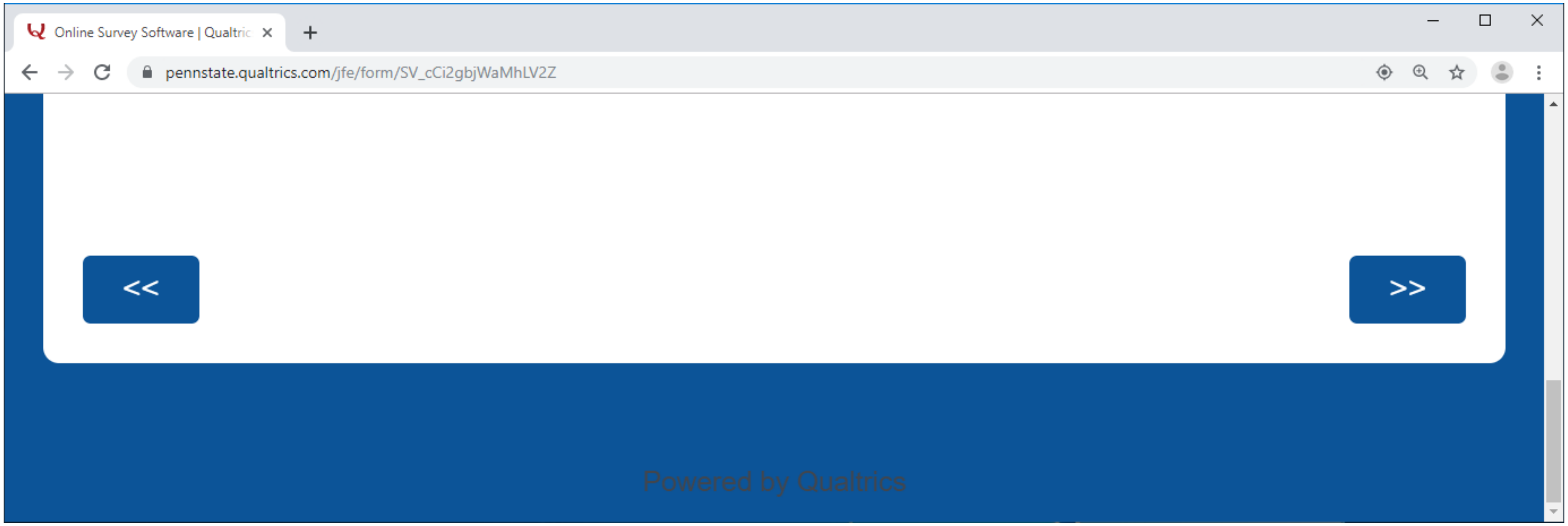
Environment




Online Survey Software | Qualtric
pennstate.qualtrics.com/jfe/form/SV_cCi2gbjWaMhLV2Z
If you were indoors at the time of the sonic thump or reminder, were your windows open or closed?
Open
Closed
I was not indoors
>>

Additional Comments




Online Survey Software | Qualtric
pennstate.qualtrics.com/jfe/form/SV_cCi2gbjWaMhLV2Z
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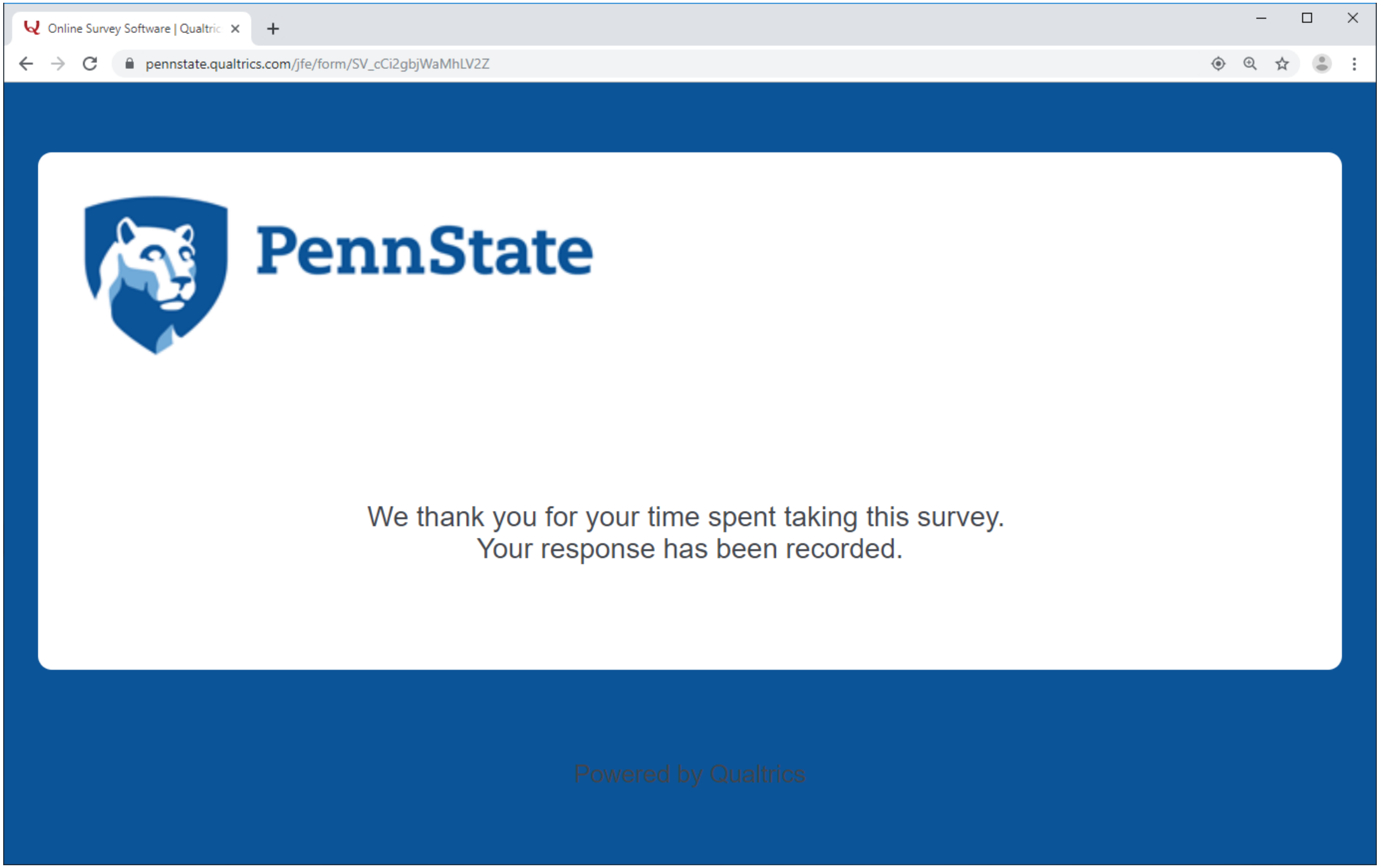
Powered by Qualtrics

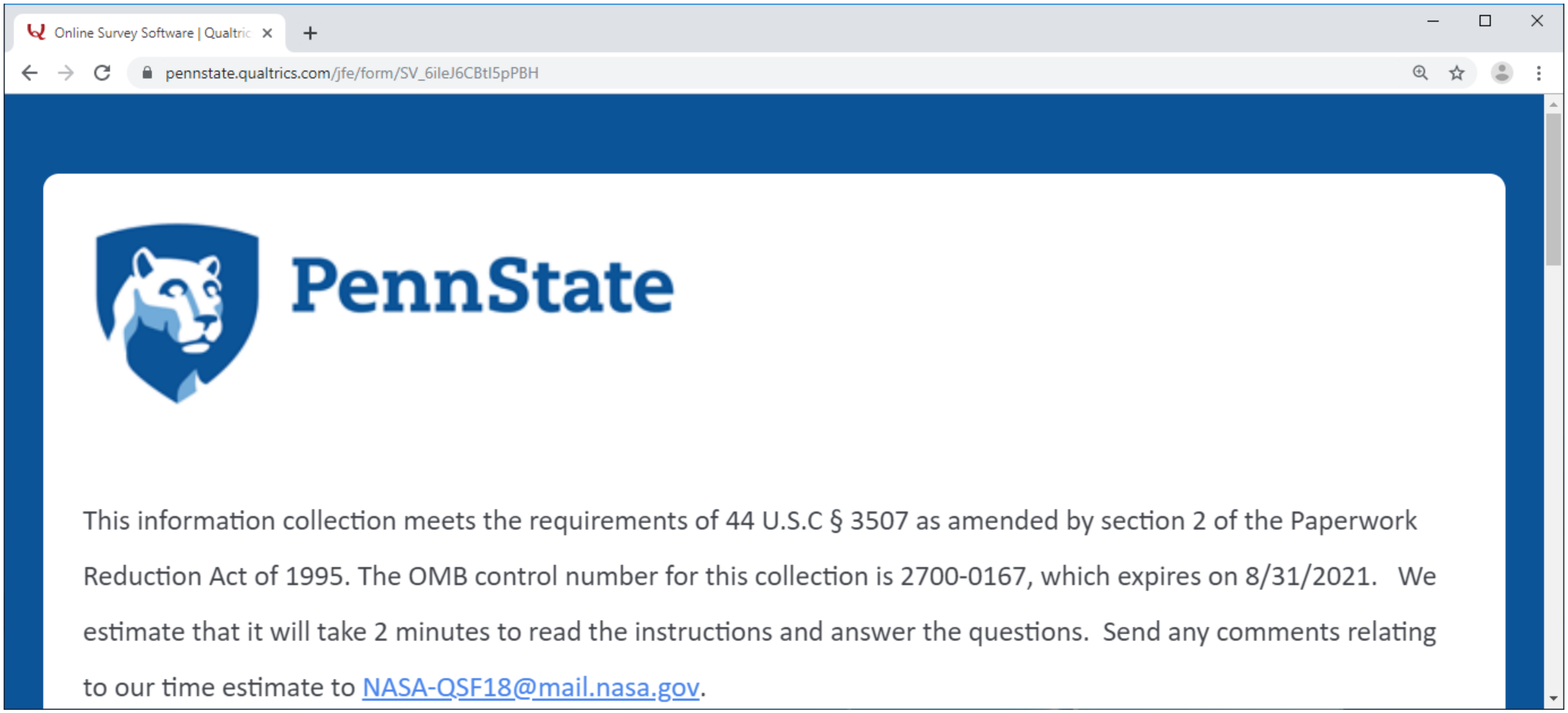
End of Single Event Thank You



Daily Summary

Note: The survey was not openly available online. Each participant received a unique link so that only those who were enrolled could complete the surveys.

Date of Response with Inquiry if Sonic Thump was Heard on That Date



Online Survey Software | Qualtric

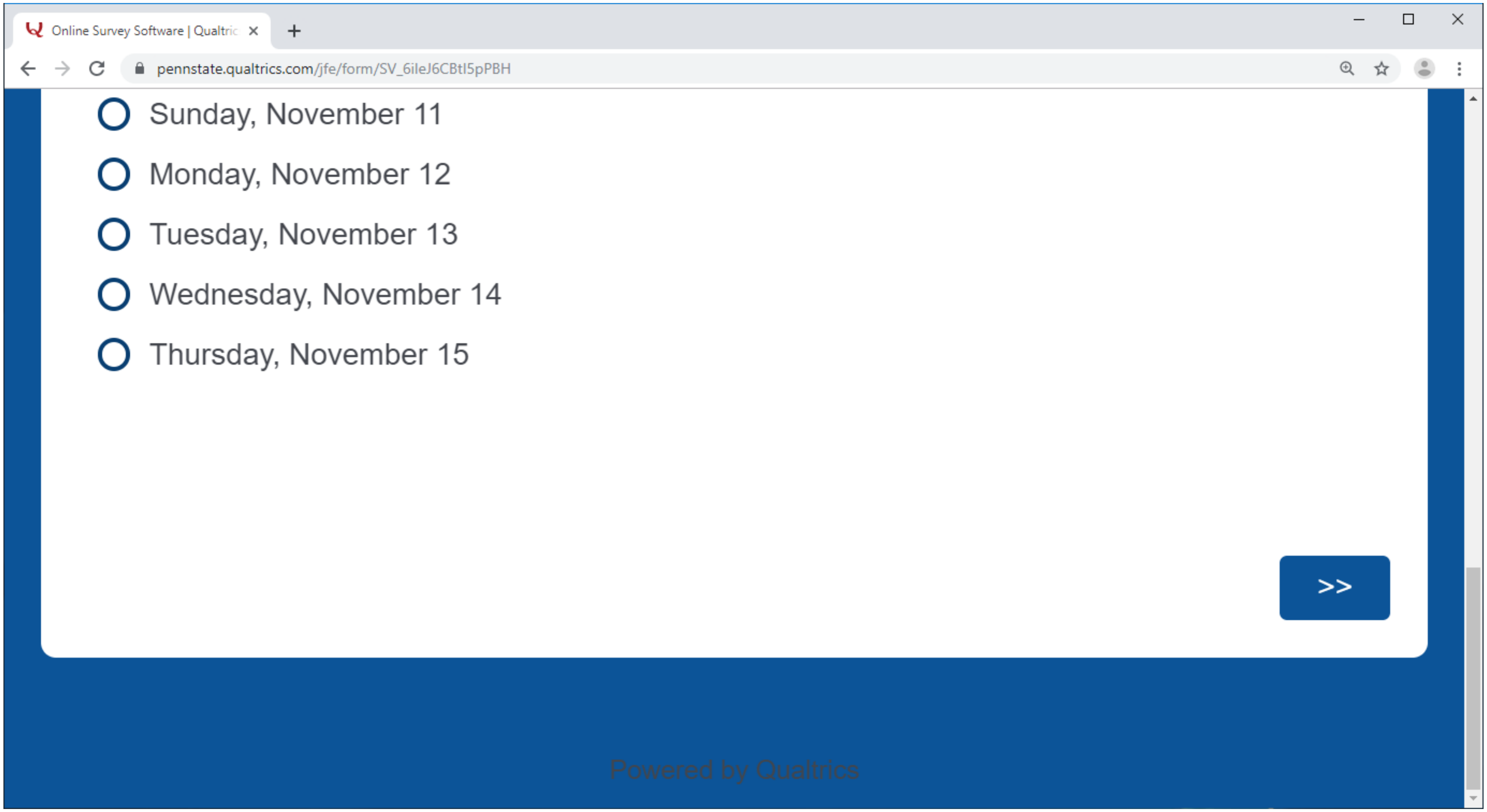
pennstate.qualtrics.com/jfe/form/SV_6ileJ6CBtI5pPBH

Quiet Supersonic Flights 2018 Community Test
Daily Response to Sonic Thumps

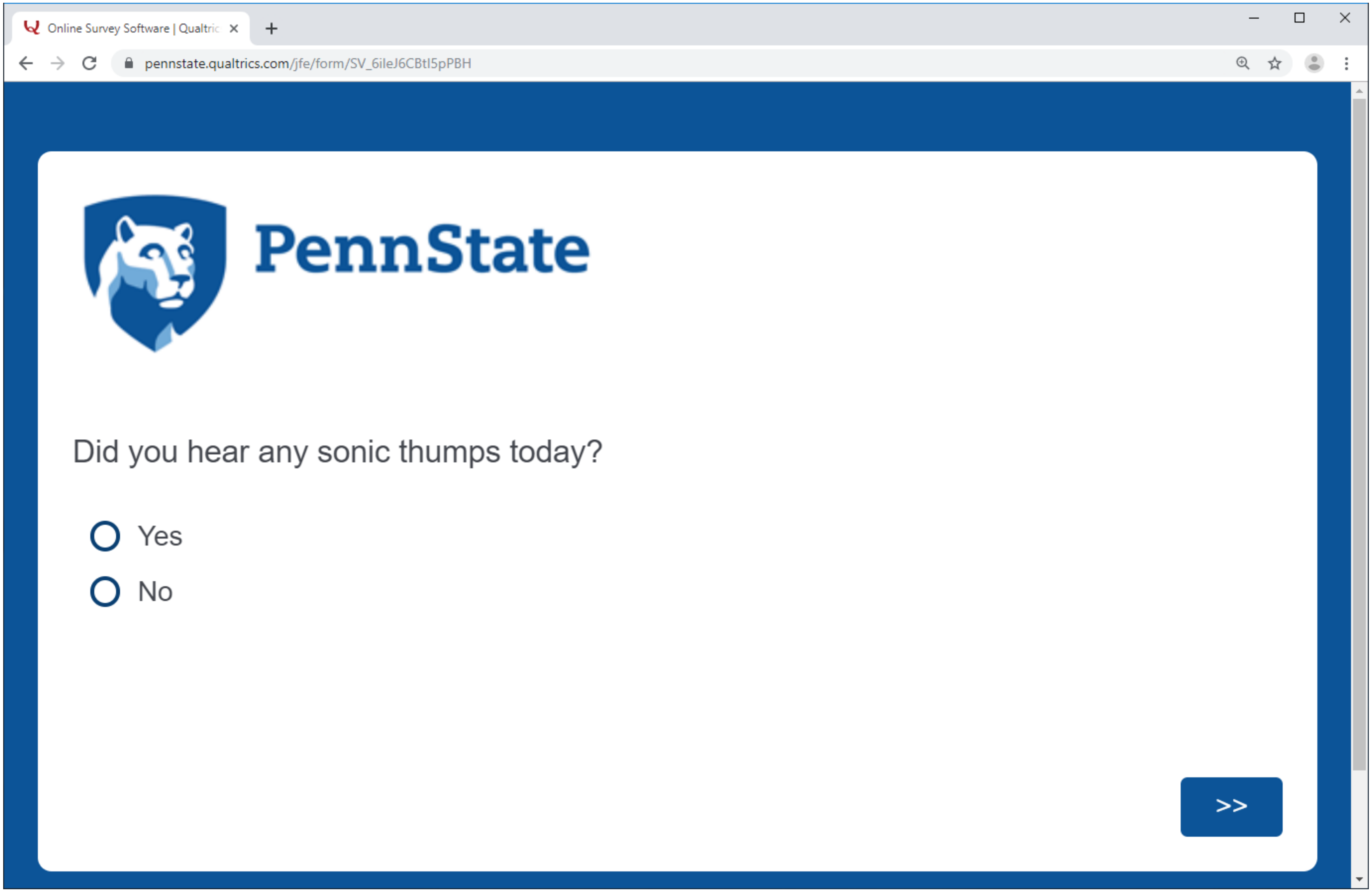
Daily Summary Response Form

Please select today's date

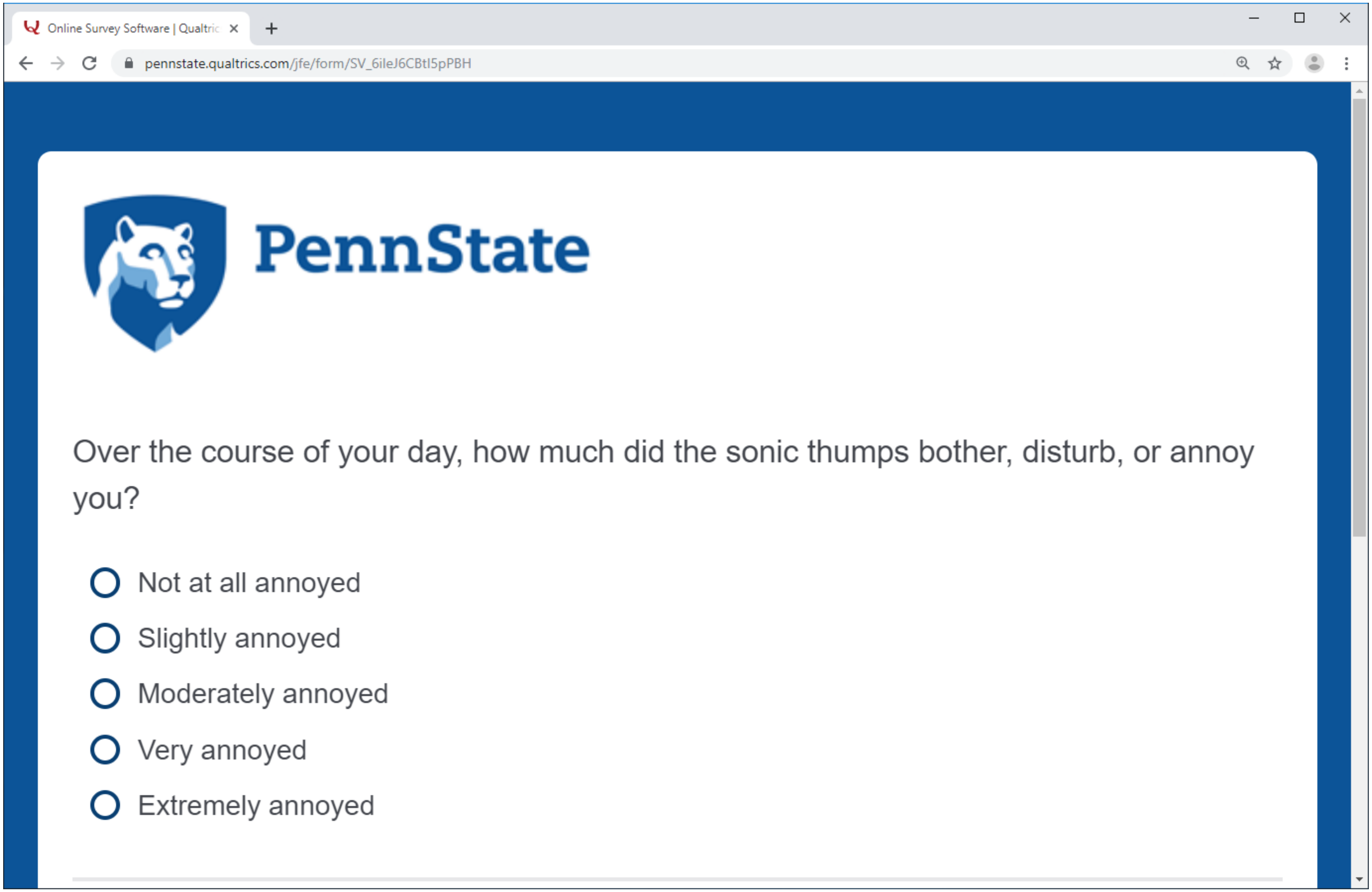
- ○ Monday, November 5
- ○ Tuesday, November 6
- ○ Wednesday, November 7
- ○ Thursday, November 8
- ○ Friday, November 9
- ○ Saturday, November 10


Online Survey Software | Qualtric
pennstate.qualtrics.com/jfe/form/SV_6ileJ6CBtI5pPBH
Sunday, November 11
Monday, November 12
Tuesday, November 13
Wednesday, November 14
Thursday, November 15
>>
Powered by Qualtrics

Daily Annoyance and Startle Summary



If answer to hearing sonic thumps today is No, survey skips to ask about time period at home. If Yes, survey asks about annoyance and the like:

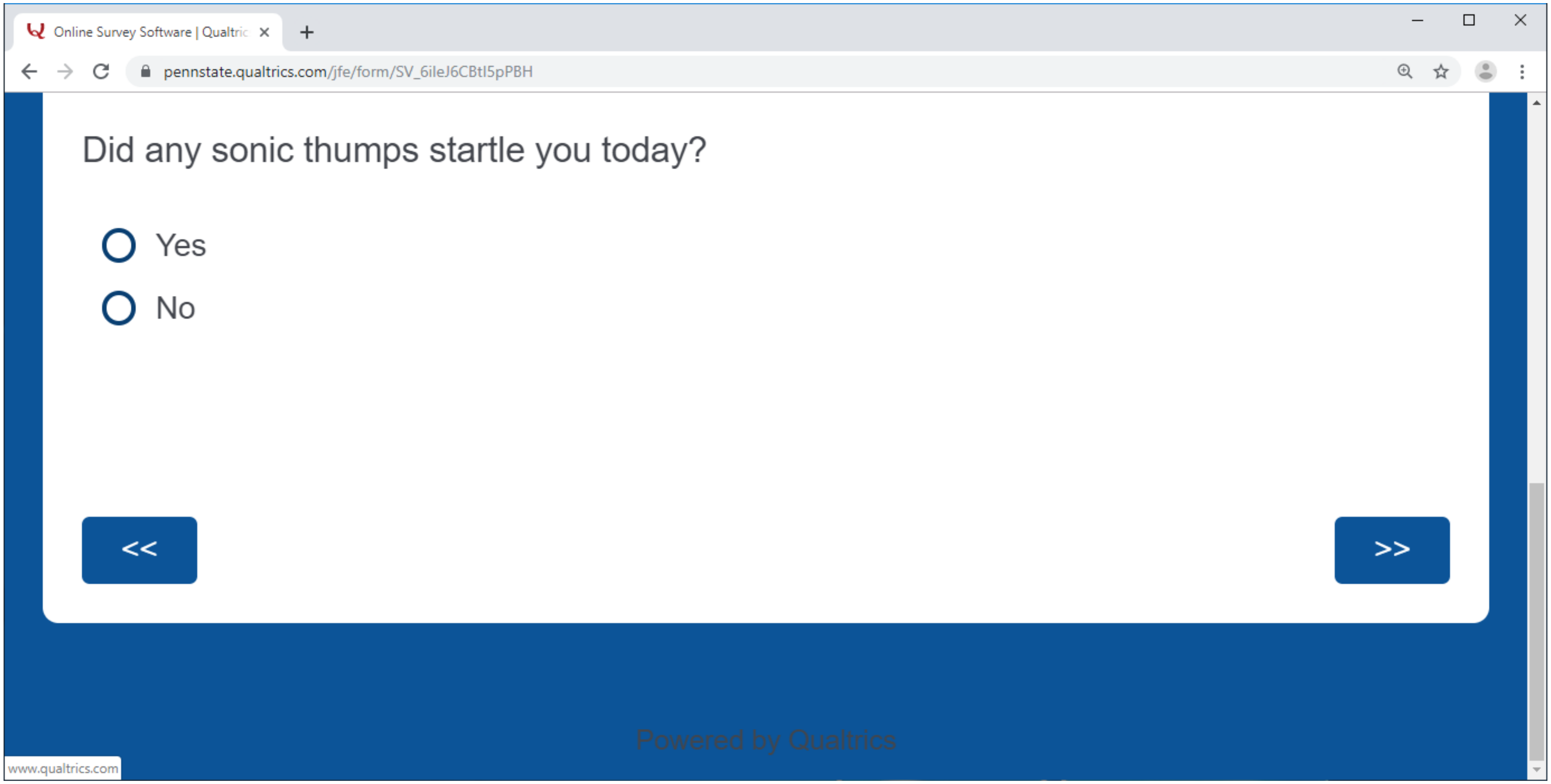

Online Survey Software | Qualtric

pennstate.qualtrics.com/jfe/form/SV_6ileJ6CBtl5pPBH

PennState

Over the course of your day, how much did the sonic thumps bother, disturb, or annoy you?

- Not at all annoyed
- Slightly annoyed
- Moderately annoyed
- Very annoyed
- Extremely annoyed


Online Survey Software | Qualtric

pennstate.qualtrics.com/jfe/form/SV_6ileJ6CBtI5pPBH

Did any sonic thumps startle you today?

Yes

No

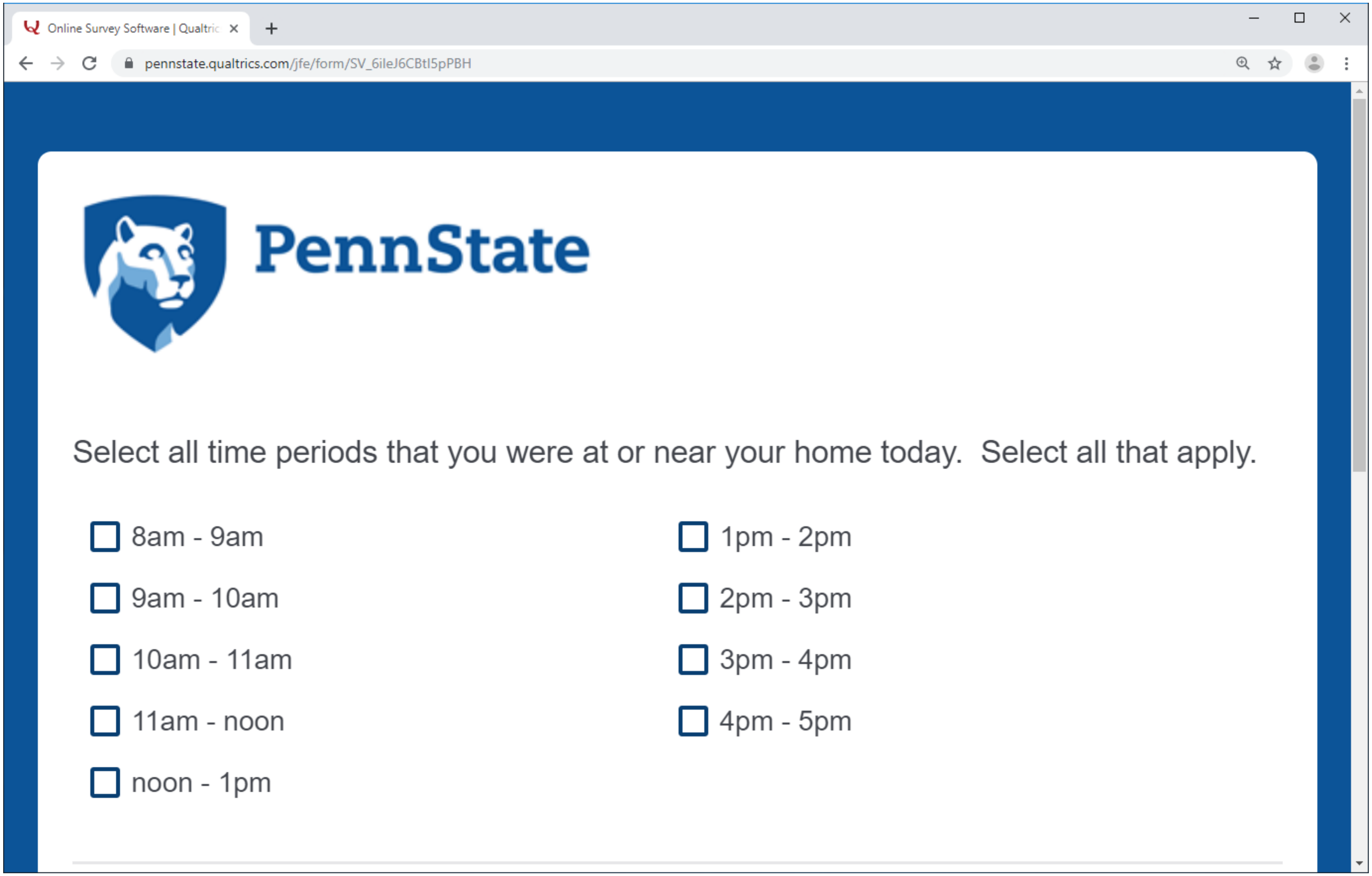
<<

>>

Powered by Qualtrics

www.qualtrics.com

Time Periods at or Near Home and Work



Online Survey Software | Qualtrics

pennstate.qualtrics.com/jfe/form/SV_6ileJ6CBtI5pPBH

PennState

Select all time periods that you were at or near your home today. Select all that apply.

- ☐ 8am - 9am
- ☐ 9am - 10am
- ☐ 10am - 11am
- ☐ 11am - noon
- ☐ noon - 1pm
- ☐ 1pm - 2pm
- ☐ 2pm - 3pm
- ☐ 3pm - 4pm
- ☐ 4pm - 5pm

Online Survey Software | Qualtrics

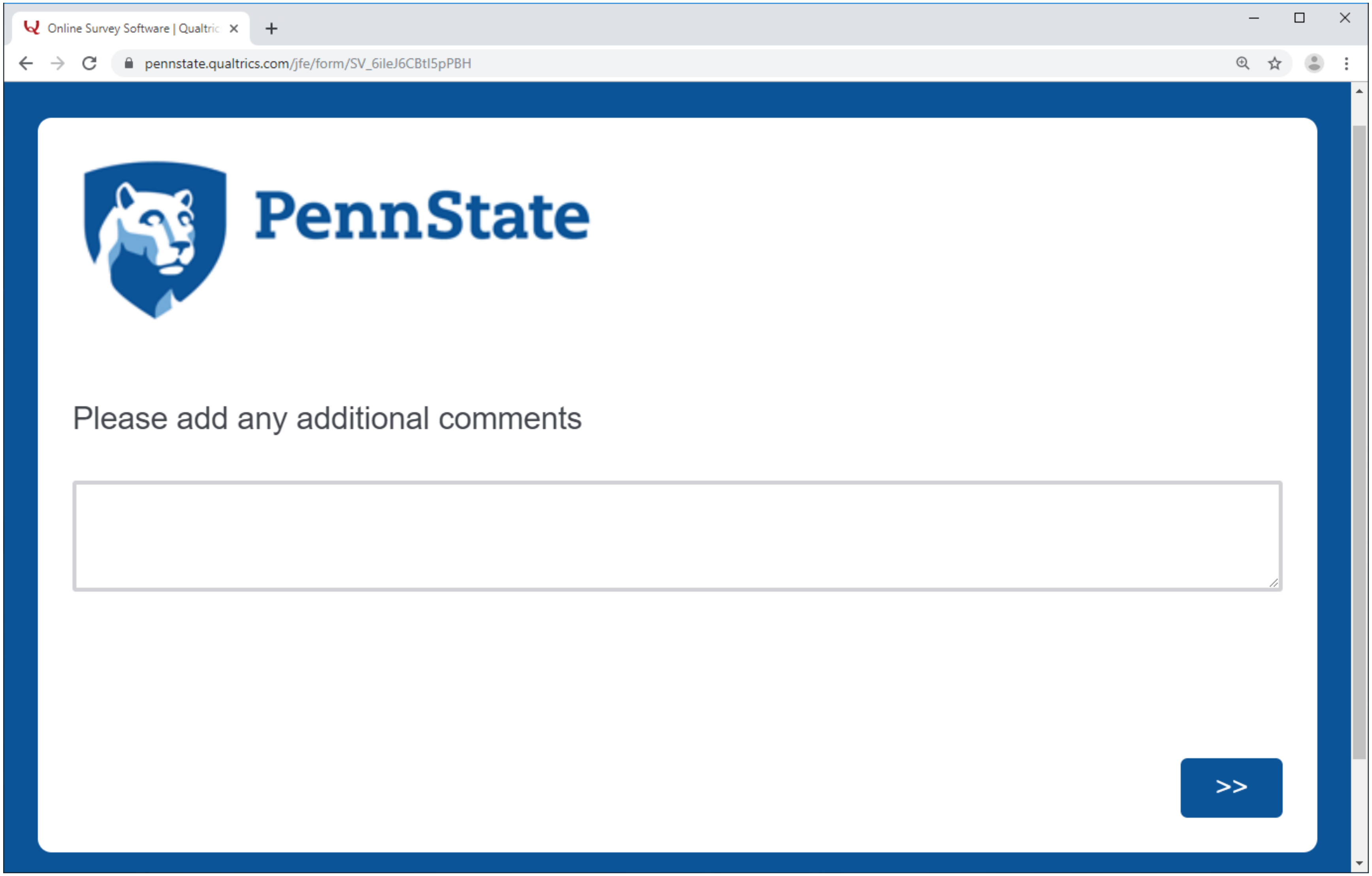
pennstate.qualtrics.com/jfe/form/SV_6ileJ6CBtI5pPBH

Select all time periods that you were **at or near work** today. Select all that apply.

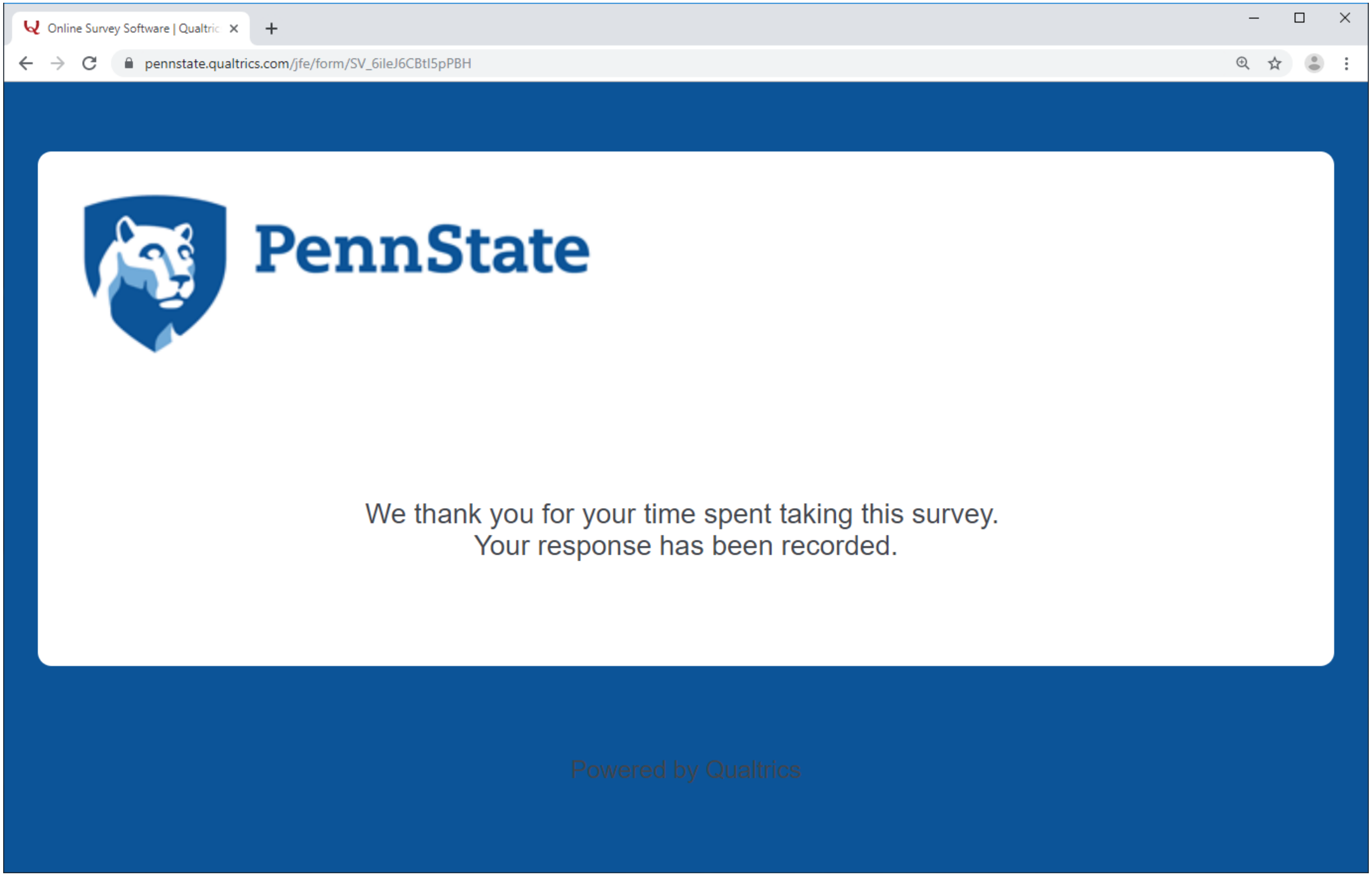
- ☐ 8am - 9am
- ☐ 9am - 10am
- ☐ 10am - 11am
- ☐ 11am - noon
- ☐ noon - 1pm
- ☐ 1pm - 2pm
- ☐ 2pm - 3pm
- ☐ 3pm - 4pm
- ☐ 4pm - 5pm

<< >>

Additional Comments

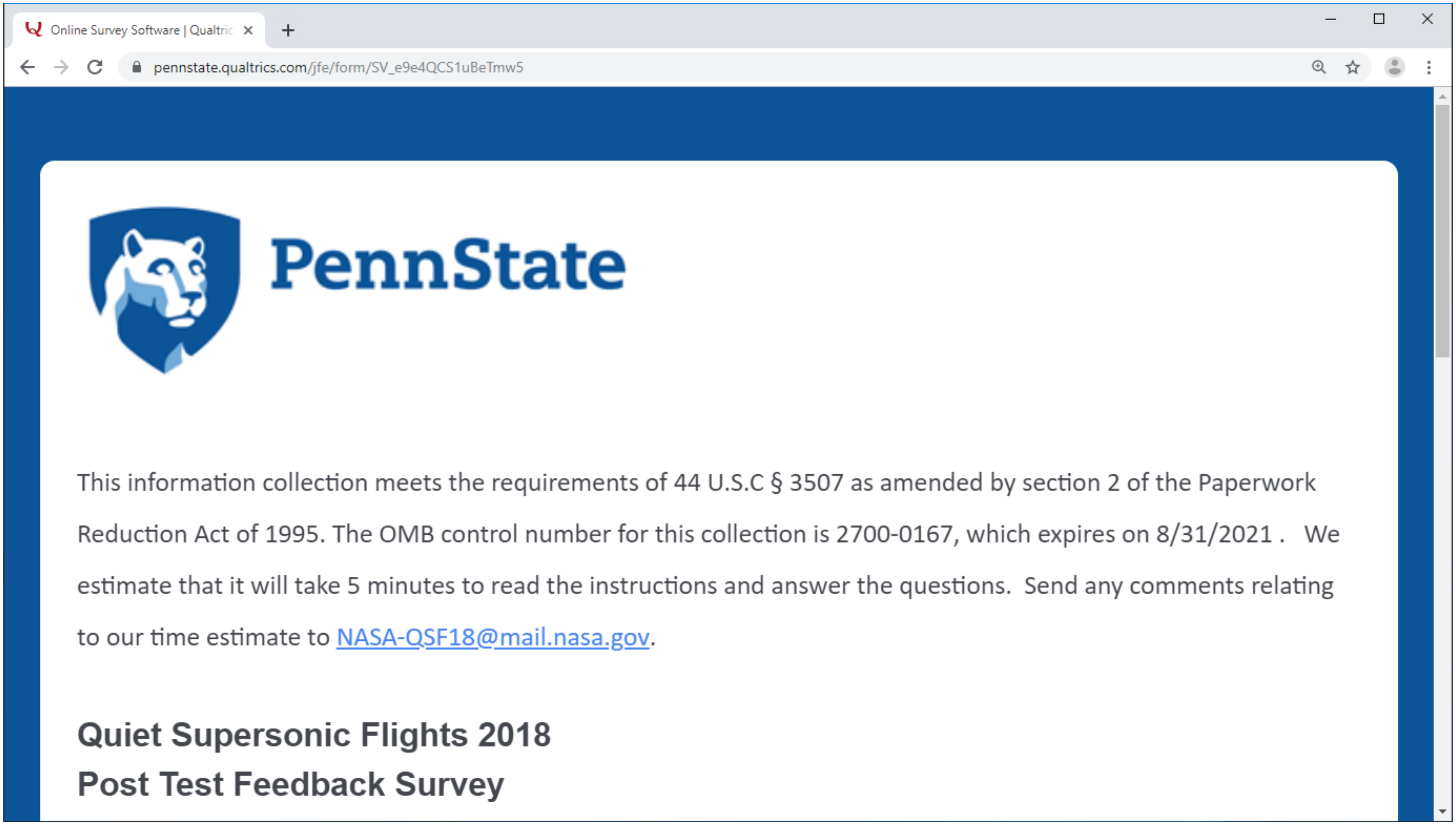


End of Daily Summary Thank You



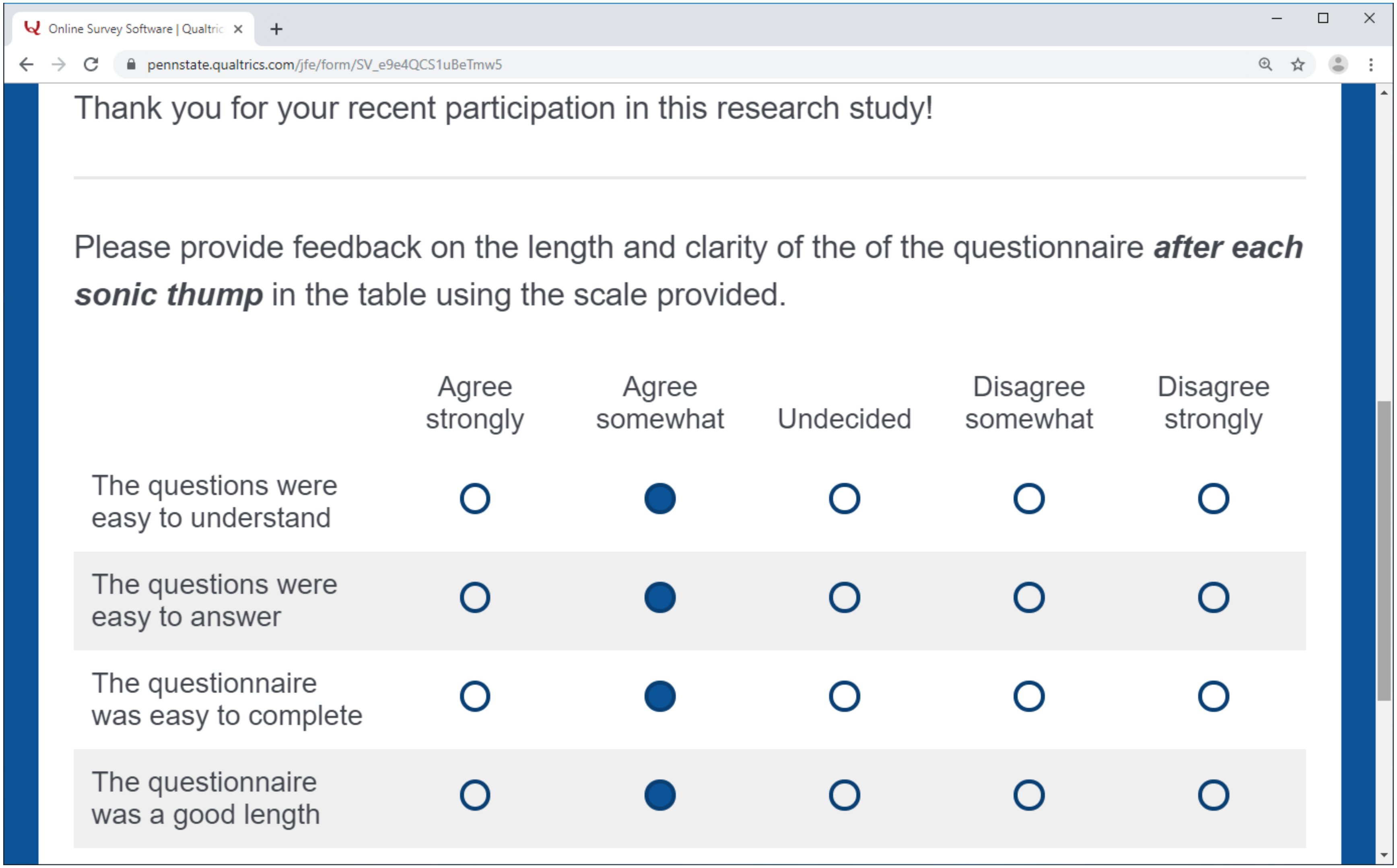
QSF18 Post Test Feedback

Ease of Completing Single Event Survey



This information collection meets the requirements of 44 U.S.C § 3507 as amended by section 2 of the Paperwork Reduction Act of 1995. The OMB control number for this collection is 2700-0167, which expires on 8/31/2021 . We estimate that it will take 5 minutes to read the instructions and answer the questions. Send any comments relating to our time estimate to NASA-QSF18@mail.nasa.gov.

Quiet Supersonic Flights 2018
Post Test Feedback Survey



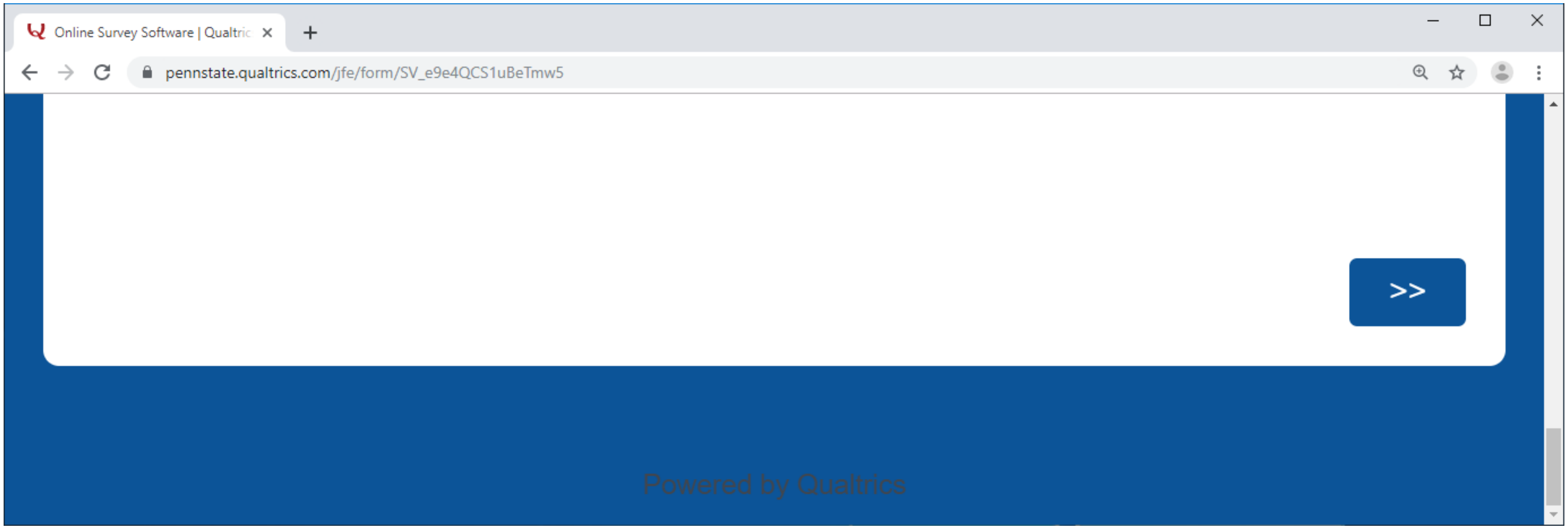
Online Survey Software | Qualtric

pennstate.qualtrics.com/jfe/form/SV_e9e4QCS1uBeTmw5

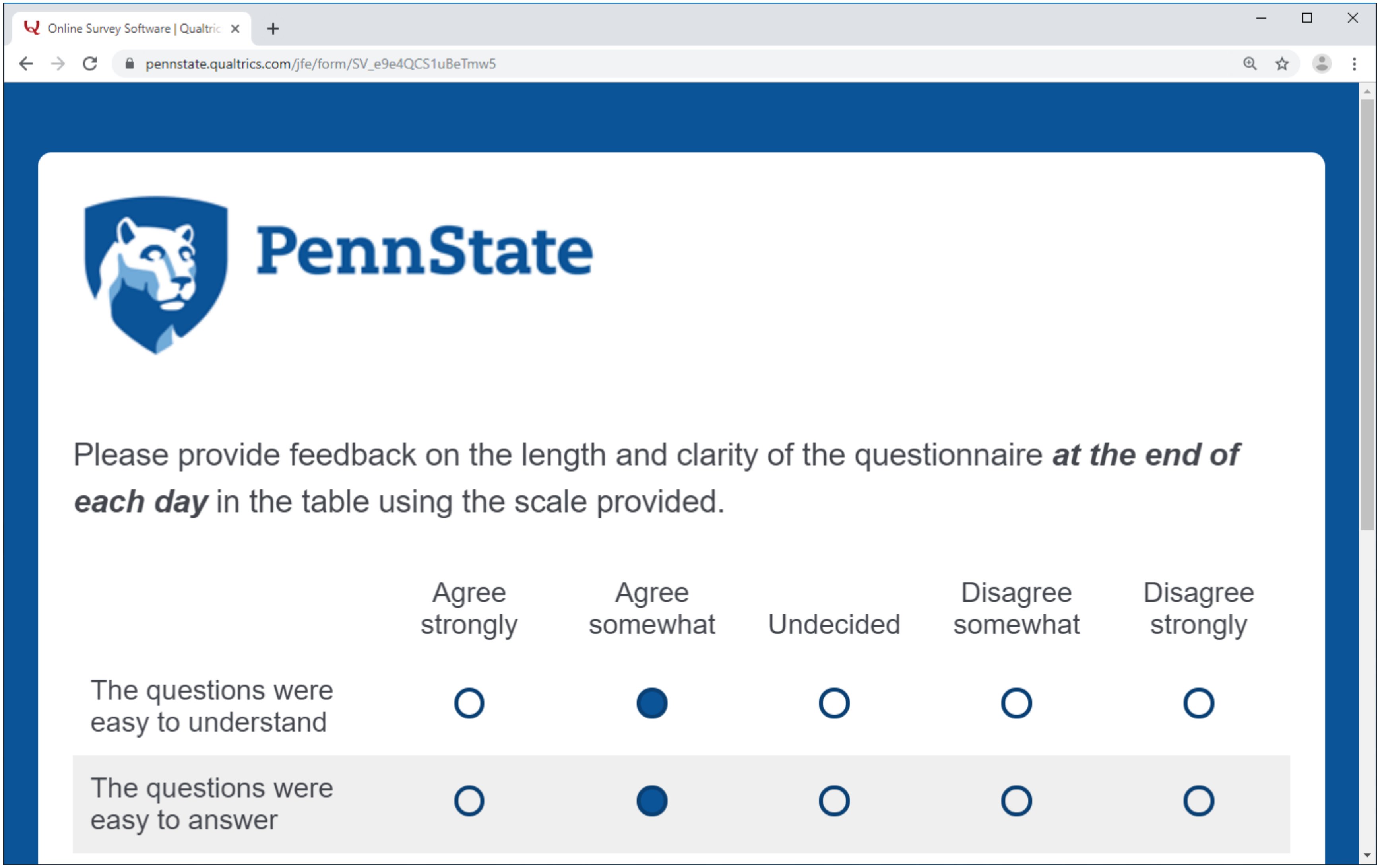
Thank you for your recent participation in this research study!

Please provide feedback on the length and clarity of the of the questionnaire ***after each sonic thump*** in the table using the scale provided.

	Agree strongly	Agree somewhat	Undecided	Disagree somewhat	Disagree strongly
The questions were easy to understand	○	●	○	○	○
The questions were easy to answer	○	●	○	○	○
The questionnaire was easy to complete	○	●	○	○	○
The questionnaire was a good length	○	●	○	○	○


Online Survey Software | Qualtric
pennstate.qualtrics.com/jfe/form/SV_e9e4QCS1uBeTmw5
>>
Powered by Qualtrics

Ease of Completing Daily Summary

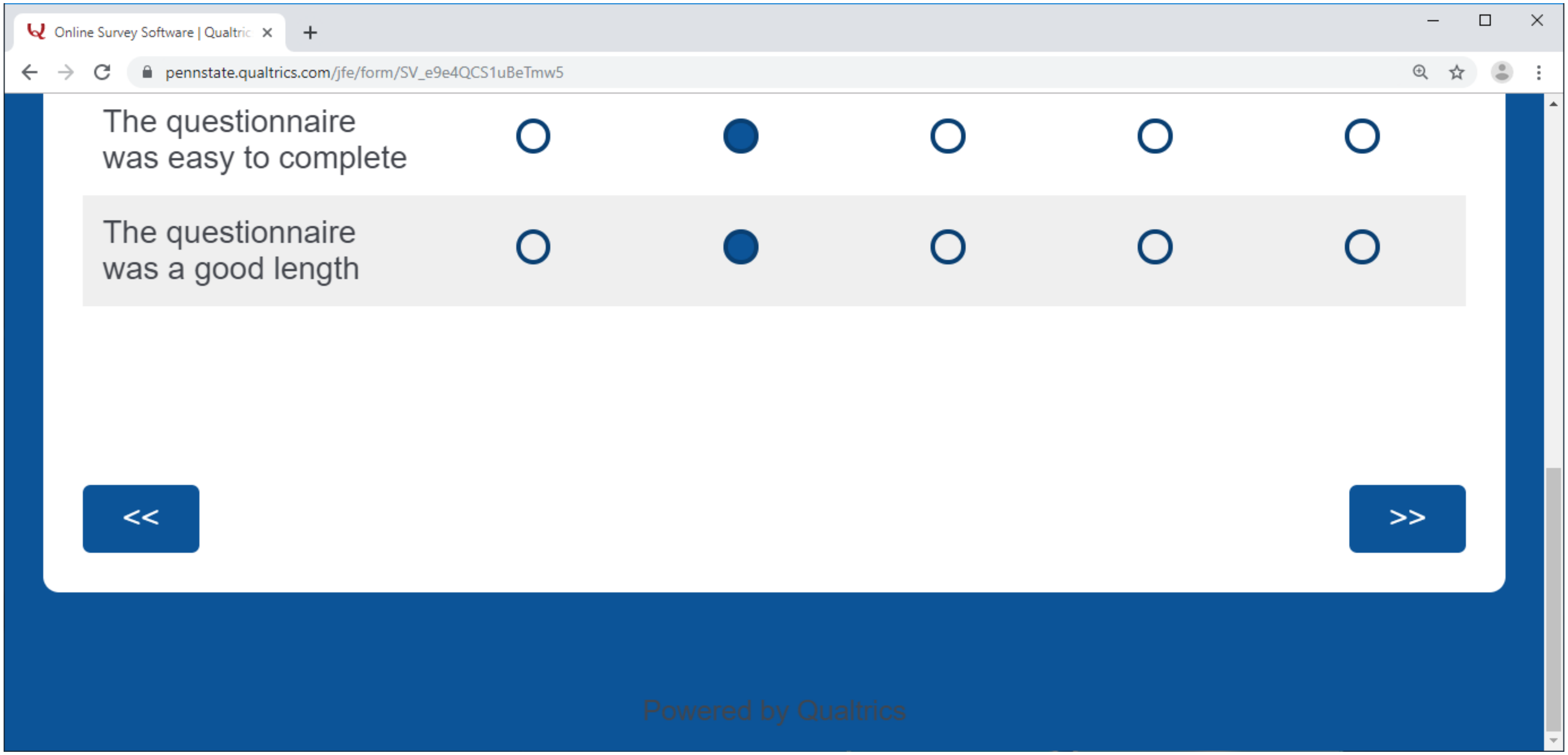

Online Survey Software | Qualtric

pennstate.qualtrics.com/jfe/form/SV_e9e4QCS1uBeTmw5

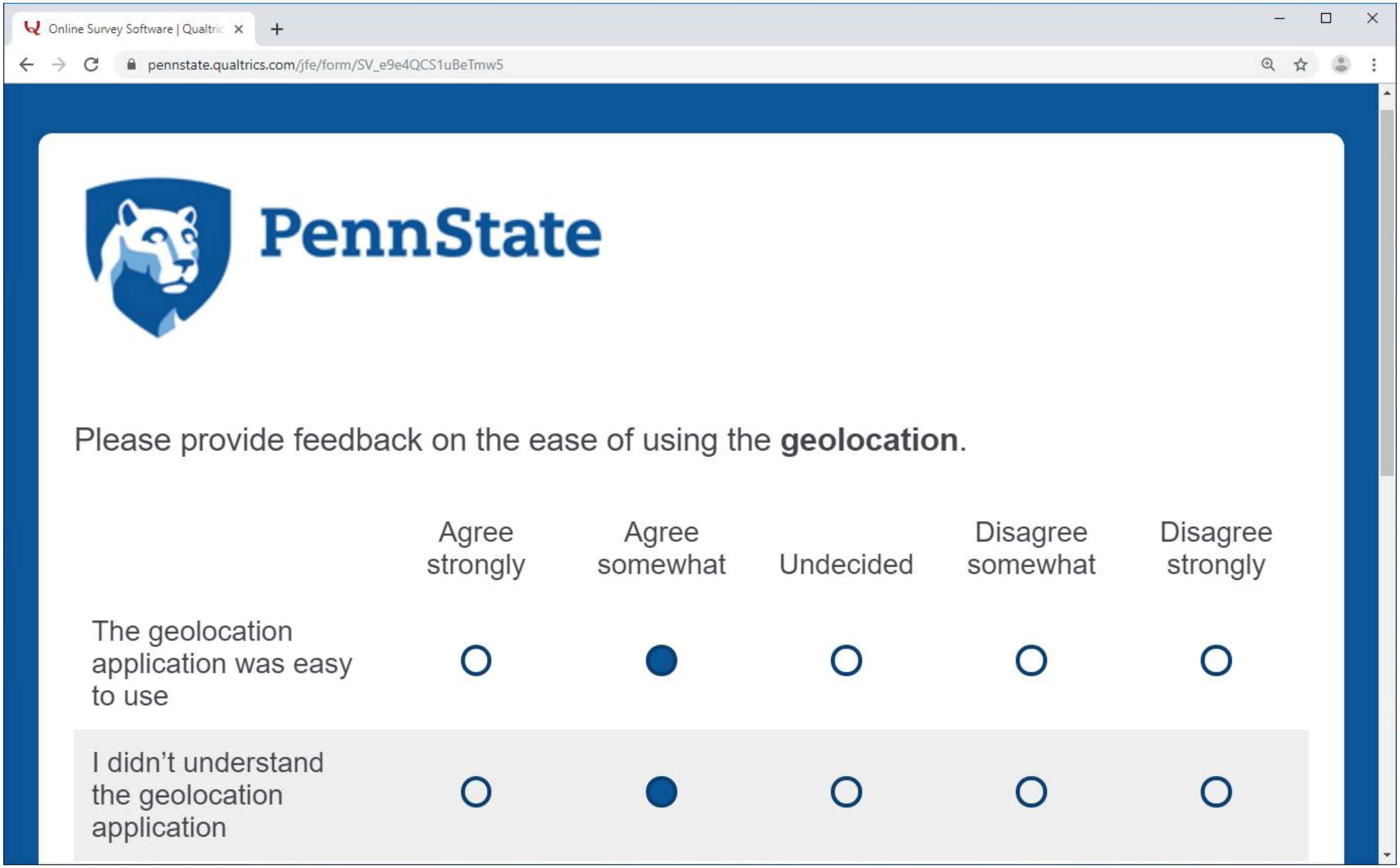
PennState

Please provide feedback on the length and clarity of the questionnaire ***at the end of each day*** in the table using the scale provided.

	Agree strongly	Agree somewhat	Undecided	Disagree somewhat	Disagree strongly
The questions were easy to understand	○	●	○	○	○
The questions were easy to answer	○	●	○	○	○


Online Survey Software | Qualtric
pennstate.qualtrics.com/jfe/form/SV_e9e4QCS1uBeTmw5
The questionnaire was easy to complete
The questionnaire was a good length
<<
>>
Powered by Qualtrics

Ease of using Geo-location

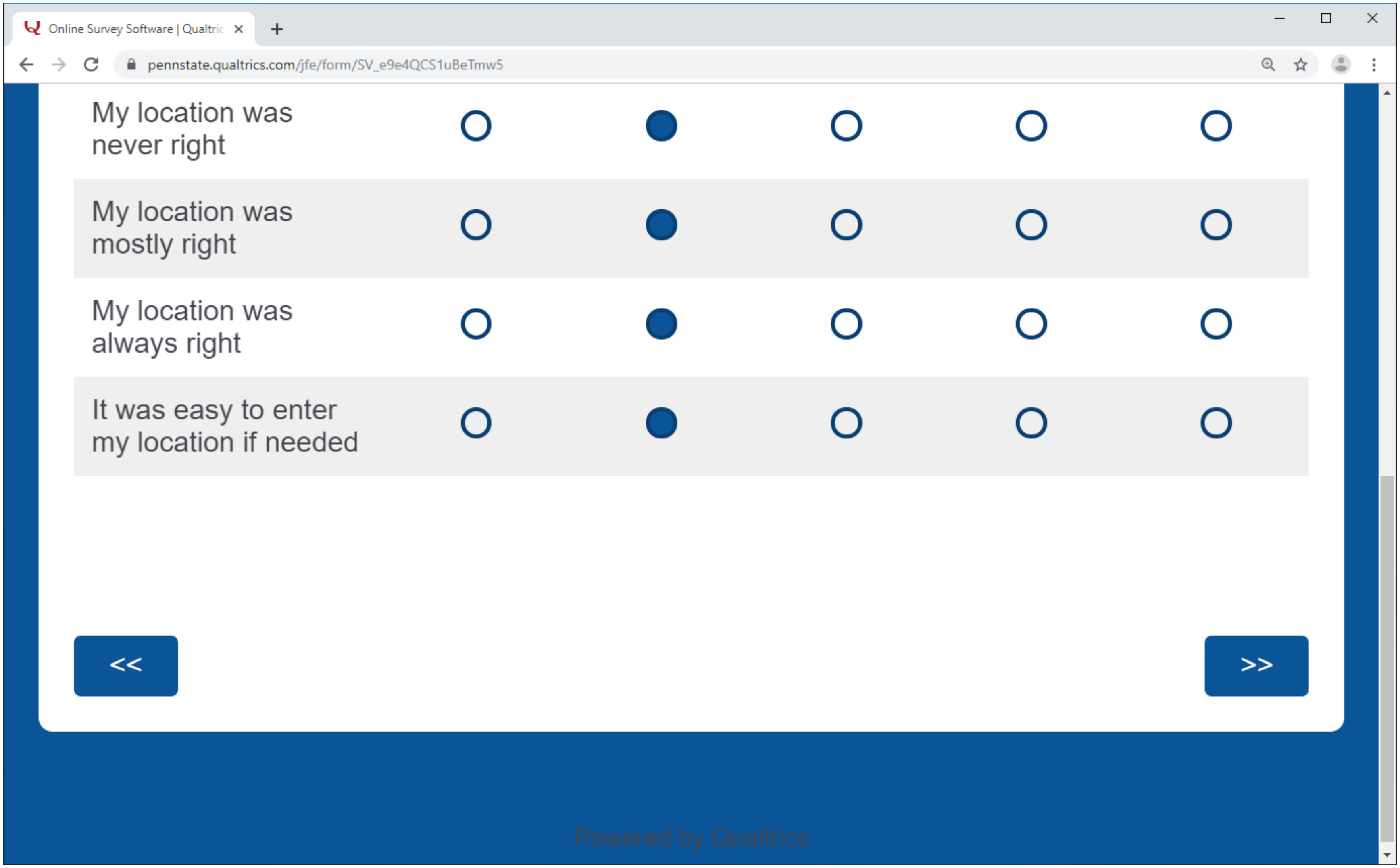

Online Survey Software | Qualtric

pennstate.qualtrics.com/jfe/form/SV_e9e4QCS1uBeTmw5

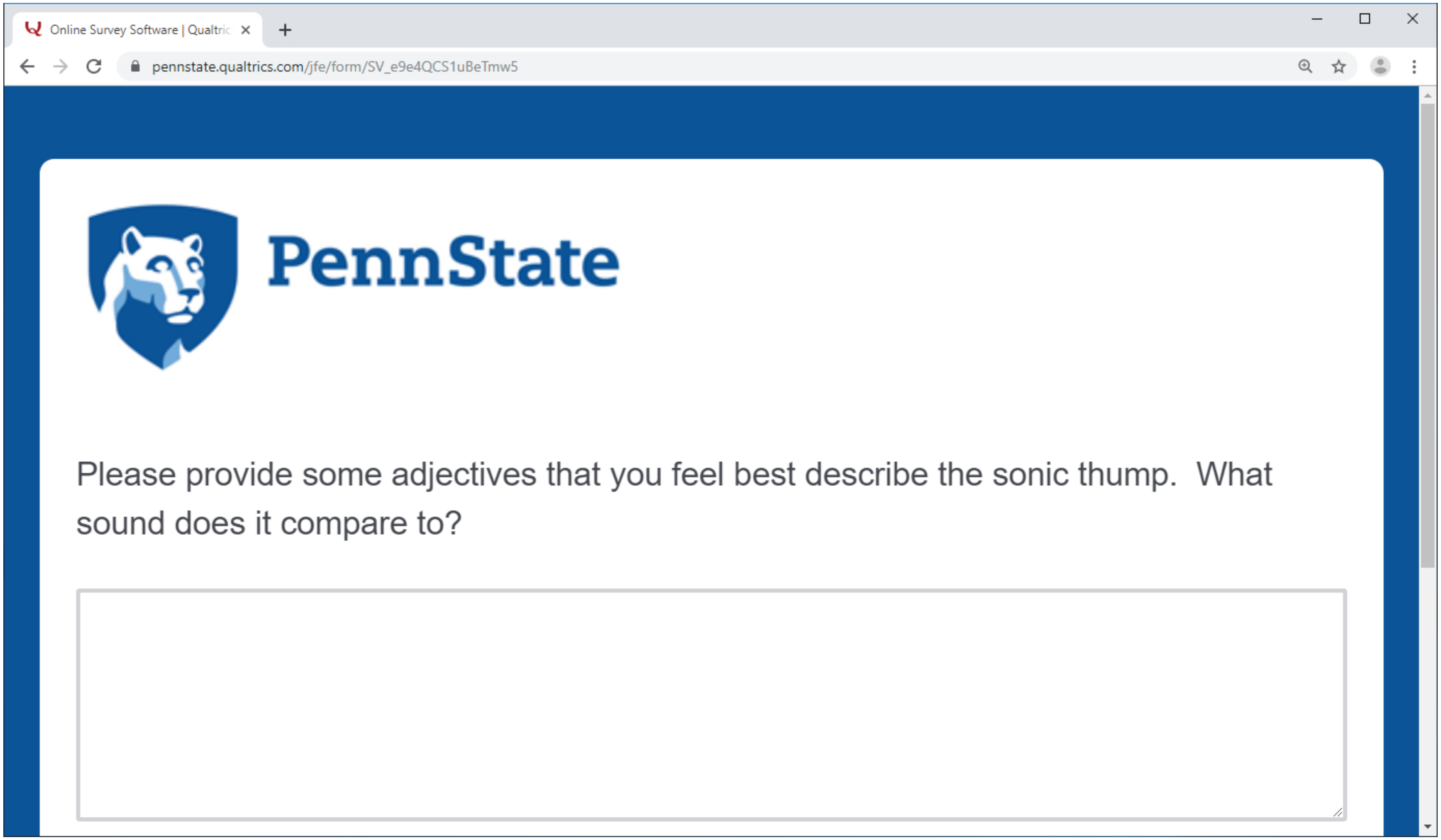
PennState

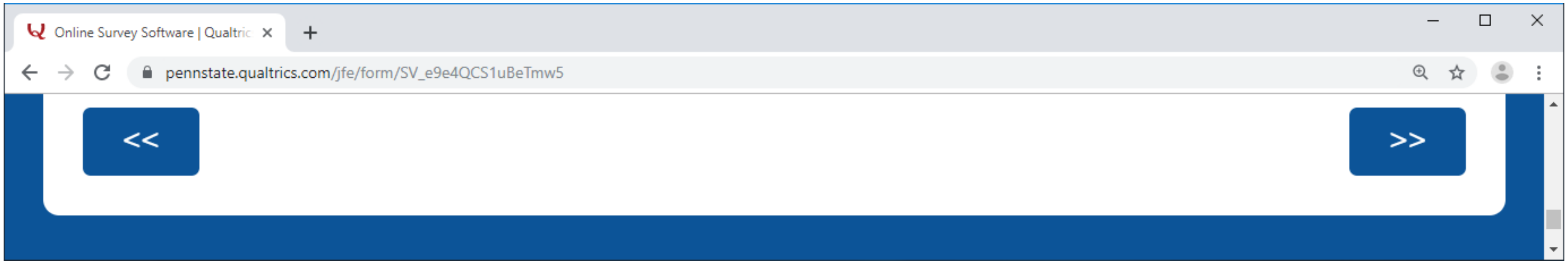
Please provide feedback on the ease of using the **geolocation**.

	Agree strongly	Agree somewhat	Undecided	Disagree somewhat	Disagree strongly
The geolocation application was easy to use	○	●	○	○	○
I didn’t understand the geolocation application	○	●	○	○	○

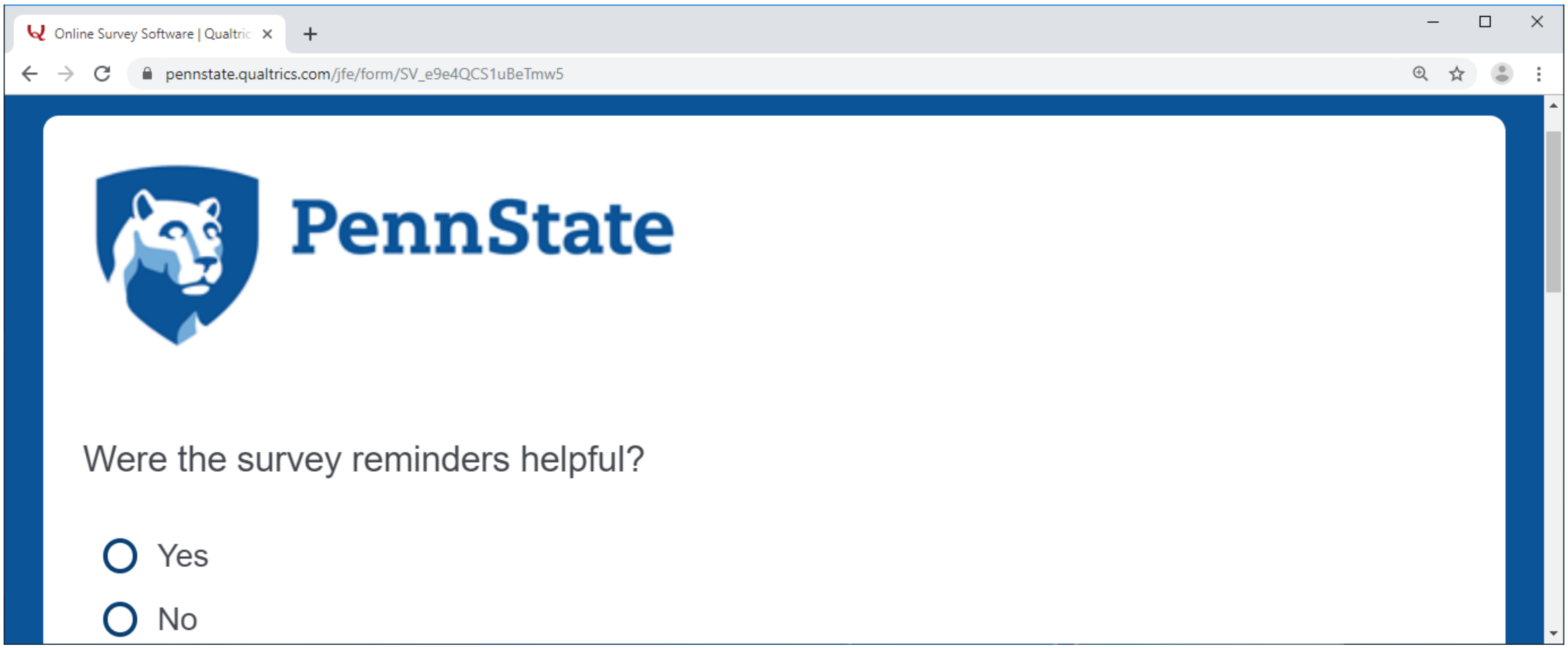

Online Survey Software | Qualtric
pennstate.qualtrics.com/jfe/form/SV_e9e4QCS1uBeTmw5
My location was never right
My location was mostly right
My location was always right
It was easy to enter my location if needed
<<
>>
Powered by Qualtrics

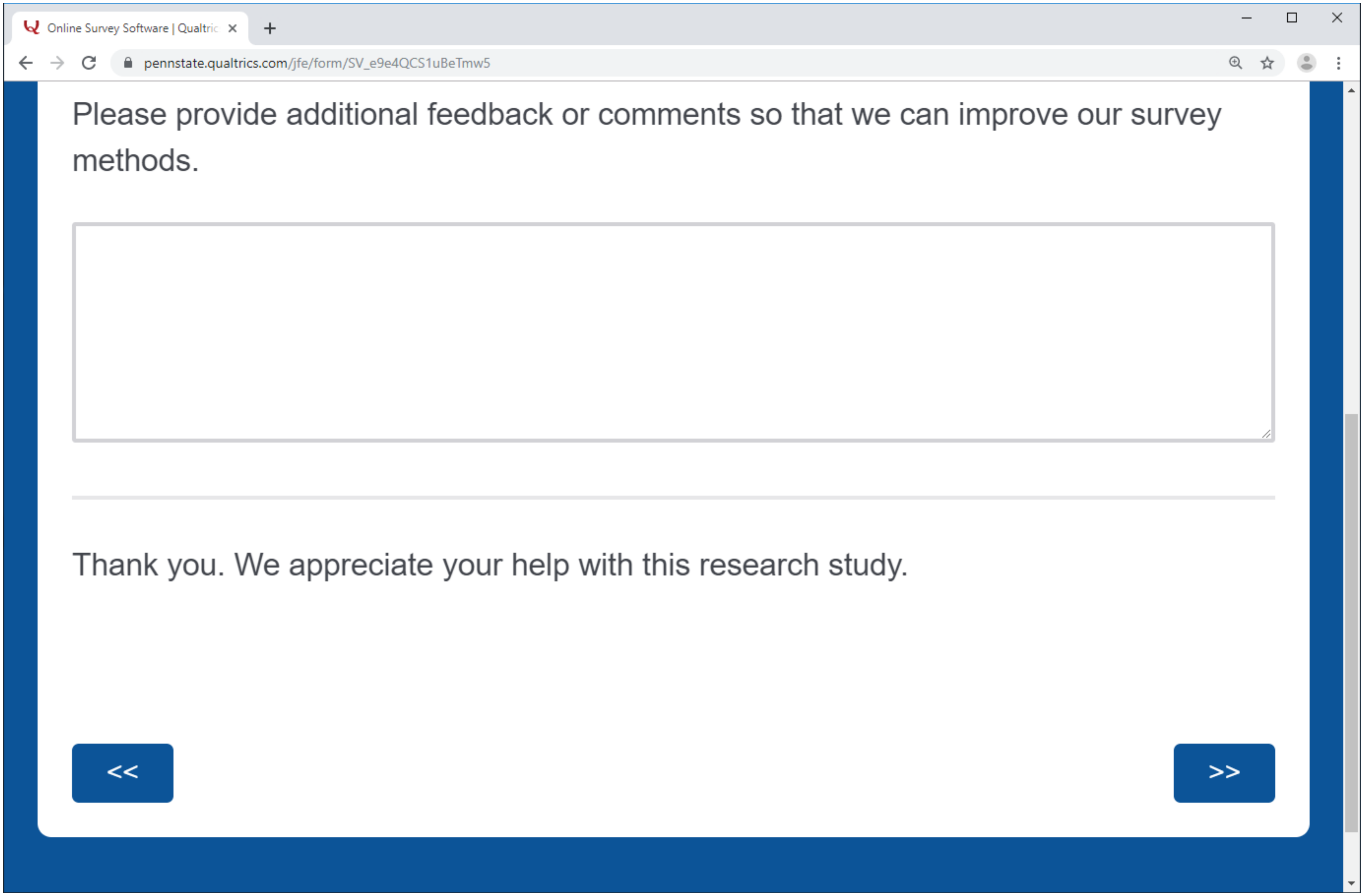
Describe Sonic Thump





Helpfulness of Survey Reminders, and Additional Feedback





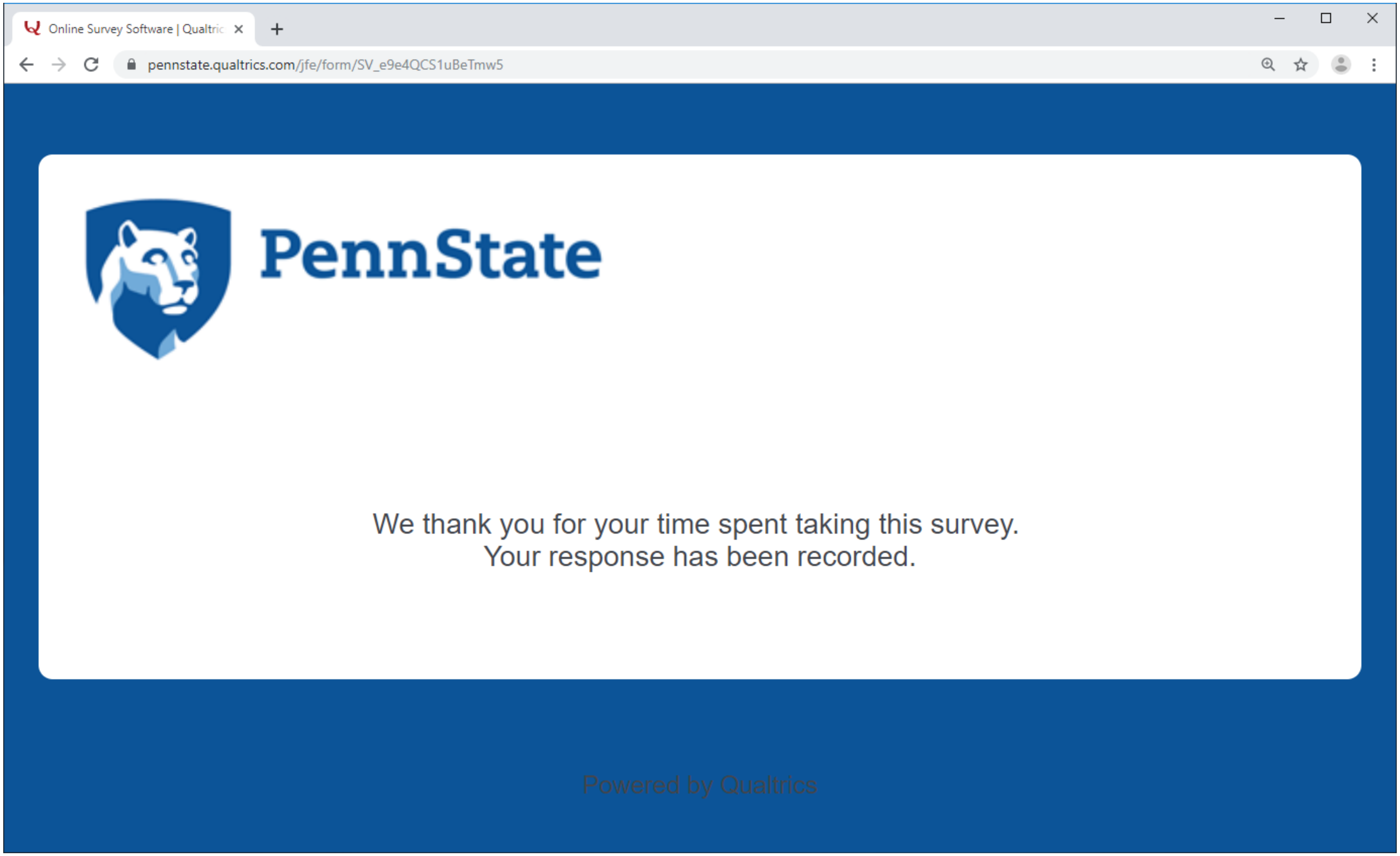
Please provide additional feedback or comments so that we can improve our survey methods.

Thank you. We appreciate your help with this research study.

<<

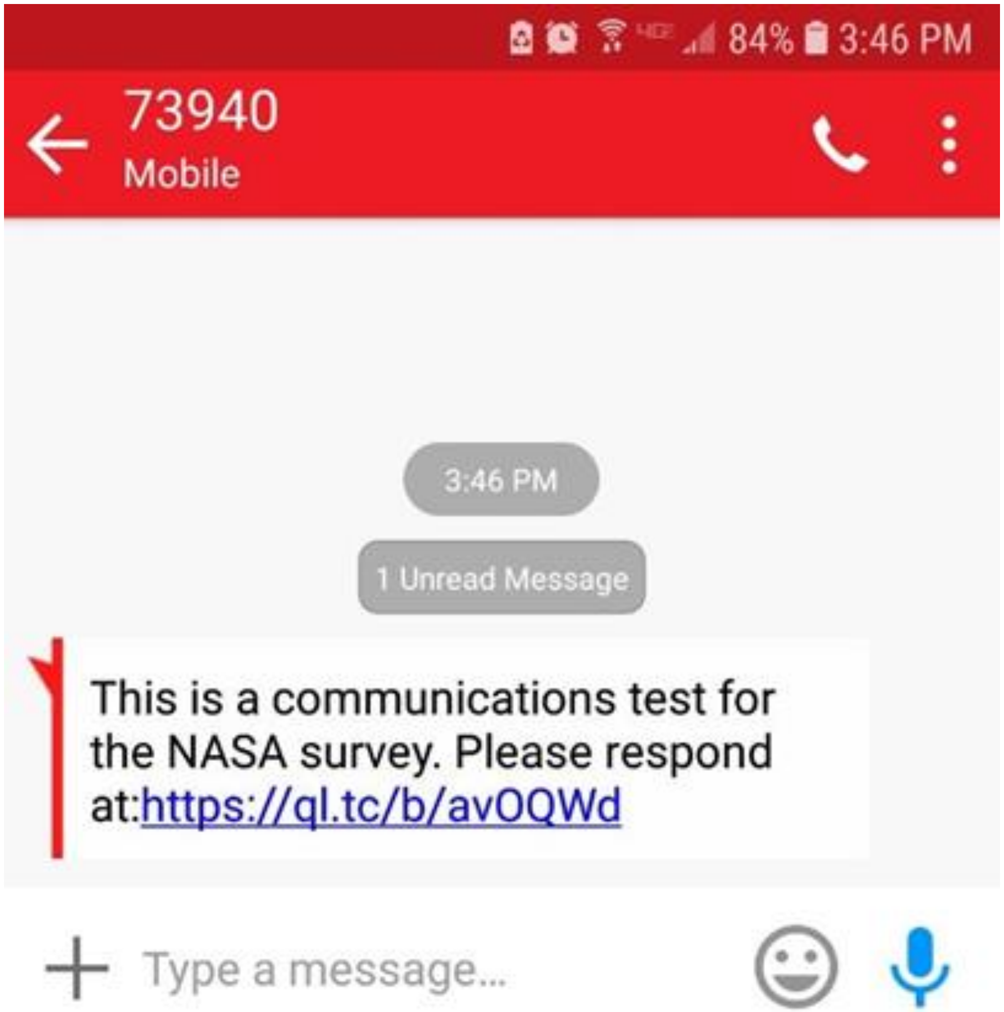
>>

End of Survey Thank You



Message Testing and Reminders

Text Testing (1/2 of the Text Message Reminder Group)



Email Testing (1/2 of the Email Reminder Group)

1 of 637

NASA Survey

Inbox ×

Penn State Survey Research Center <noreply@qemailserver.com> Unsubscribe

3:54 PM (1 minute ago)

to me

This is a communications test for the NASA survey. Please respond at:

Take the Survey

Or copy and paste the URL below into your internet browser:
https://pennstate.qualtrics.com/jfe/form/SV_d3ZcYaHZF60yWMZ?Q_DL=e8Wwa4aAHm7VOdv_d3ZcYaHZF60yWMZ_MLRP_3PMJWGrGuQJJU3z&Q_CHL=email

Follow the link to opt out of future emails:
Click here to unsubscribe

Reply   Forward

Morning Reminder Email (Everyone)

1 of 637

NASA Survey Reminder

Inbox ×

Penn State Survey Research Center <noreply@qemailserver.com> Unsubscribe

3:58 PM (0 minutes ago)

to me

Thank you in advance for participating in the NASA survey today. You can use the link below to report a sonic thump any time you hear one throughout the day.

You will also receive an email at the end of today for your daily summary survey. If you have any technical issues, please email the Penn State Survey Research Center at: srcwebsurvey@psu.edu

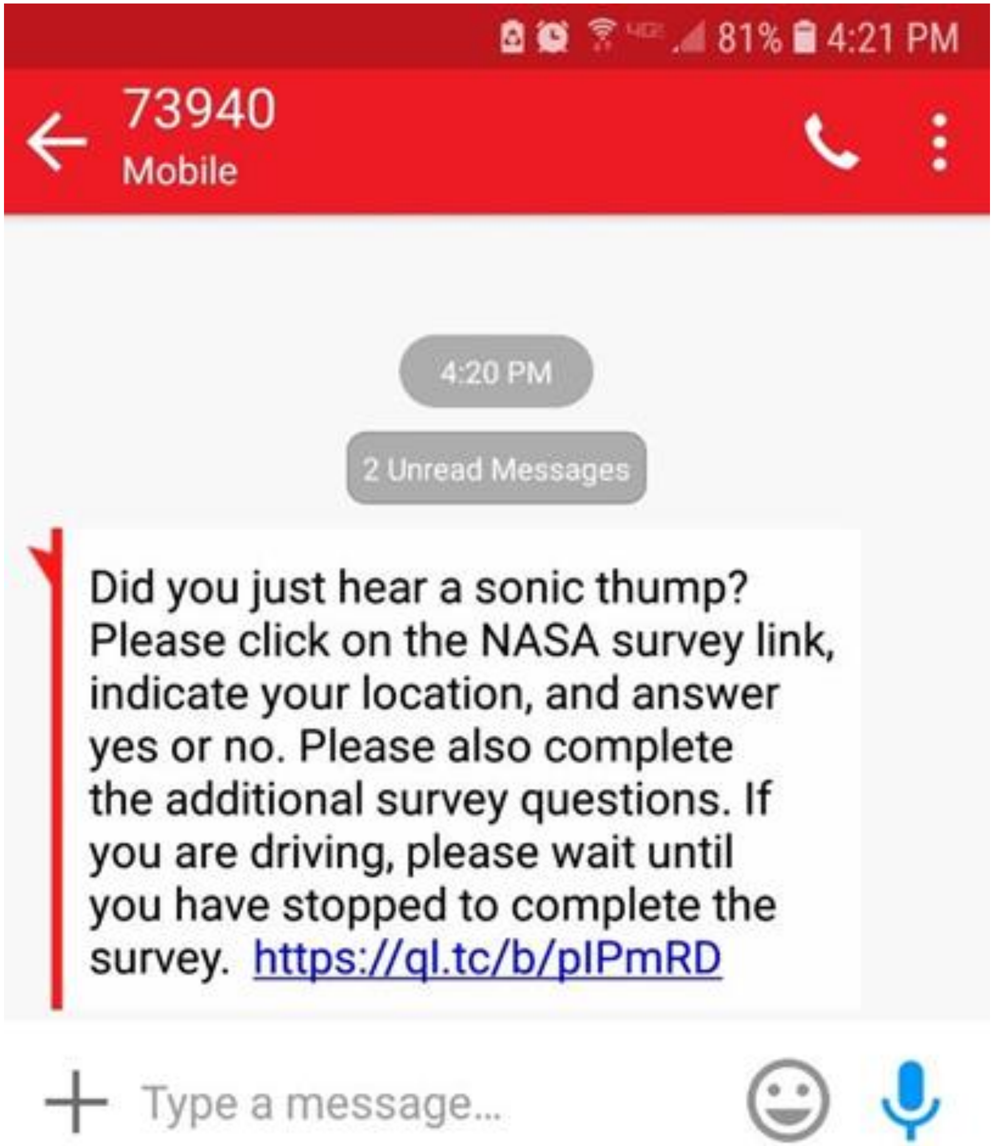
Use this link to access the NASA Survey:

Follow this link to the Survey:
Take the Survey

Or copy and paste the URL below into your internet browser:
https://pennstate.qualtrics.com/jfe/form/SV_cCi2gbjWaMhLV2Z?Q_DL=02JYVqSxYj2jEPj_cCi2gbjWaMhLV2Z_MLRP_3PMJWGrGuQJJU3z&Q_CHL=email

Follow the link to opt out of future emails:
Click here to unsubscribe

Text Reminder (1/2 of the text message group)



Email Reminder (1/2 of the Email Reminder Group)

1 of 637

NASA Survey Reminder

Inbox ×

Penn State Survey Research Center <noreply@qemailserver.com>

4:16 PM (0 minutes ago)

to me

Did you just hear a sonic thump? Please click on the NASA survey link, indicate your location, and answer yes or no. Please also complete the additional survey questions.

If you are driving, please wait until you have stopped to complete the survey.

Follow this link to the Survey:
Take the Survey

Or copy and paste the URL below into your internet browser:
https://pennstate.qualtrics.com/jfe/form/SV_cCi2gbjWaMhLV2Z?Q_DL=dgnO5UnCXafSZ49_cCi2gbjWaMhLV2Z_MLRP_3PMJWGrGuQJJU3z&Q_CHL=email

Follow the link to opt out of future emails:
Click here to unsubscribe

Reply

Forward

1 deleted message in this conversation. View message or delete forever.

Daily Summary Reminder (Everyone)

1 of 637

NASA Daily Summary Survey

Inbox ×

PSU Survey Research Center <noreply@qemailserver.com> Unsubscribe

to me

4:25 PM (0 minutes ago)

Thank you for your participation today in the NASA survey. Please complete your NASA daily summary survey via the link below. If you have any technical issues, please email the Penn State Survey Research Center at: srcwebsurvey@psu.edu.

Follow this link to the Survey:
Take the Survey

Or copy and paste the URL below into your internet browser:
https://pennstate.qualtrics.com/jfe/form/SV_6ileJ6CBtl5pPBH?Q_DL=dj1Dj0SNlaMZsNf_6ileJ6CBtl5pPBH_MLRP_3PMJWGrGuQJJU3z&Q_CHL=email

Follow the link to opt out of future emails:
Click here to unsubscribe

Reply | Forward

Final Feedback Reminder (Everyone)

1 of 637

NASA Final Feedback Survey

Inbox ×

PSU Survey Research Center <noreply@qemailserver.com> Unsubscribe

4:28 PM (0 minutes ago)

to me

We appreciate your participation in this NASA research study! At this time, please complete the final feedback survey.

You will receive compensation of $25 per week for the two weeks of the survey for a total amount of $50 as an expression of appreciation. If the survey is terminated before the end of the first week, participants who completed the survey until its termination will receive $25. If the survey is terminated after the first week, but before the end of the second week, participants who completed the survey until its termination will receive $50. Please allow 1 month for the compensation to be processed.

If you have any technical issues, please email the Penn State Survey Research Center at srcwebsurvey@psu.edu.

Follow this link to the Survey:
Take the Survey

Or copy and paste the URL below into your internet browser:
https://pennstate.qualtrics.com/jfe/form/SV_e9e4QCS1uBeTmw5?Q_DL=6ArhmBi36Dtyk6h_e9e4QCS1uBeTmw5_MLRP_3PMJWGrGuQJJU3z&Q_CHL=email

Follow the link to opt out of future emails:
Click here to unsubscribe

Reply | Forward

L. Background Survey Summary Details

The following pages provide Appendix L. This appendix file is provided separately from the main body of the report.

QSF18 Background Survey Summary Details

This appendix provides detailed respondent demographic data obtained from surveys, plus derived noise habituation and sensitivity scales. ***Figure 1*** through ***Figure 10*** summarize the responses to standard demographic characteristics questions. ***Figure 11*** through ***Figure 14*** summarize the responses to questions regarding the respondent's perception of their own and others' ability to habituate to noise. ***Figure 15*** presents a noise habituation scale that was derived via simple summation the survey responses regarding ability to habituate to noise. Note that only the data in ***Figure 12*** through ***Figure 14*** were used to form the noise habituation scale. As discussed in the main report, statistical analysis determined that using all four questions resulted in a less reliable scale. ***Figure 16*** through ***Figure 20*** summarize the responses to survey questions regarding their annoyance by common noise sources. ***Figure 21*** presents a noise sensitivity scale that was derived via simple summation of the survey responses regarding annoyance by common noise sources.

Standard Demographic Characteristics

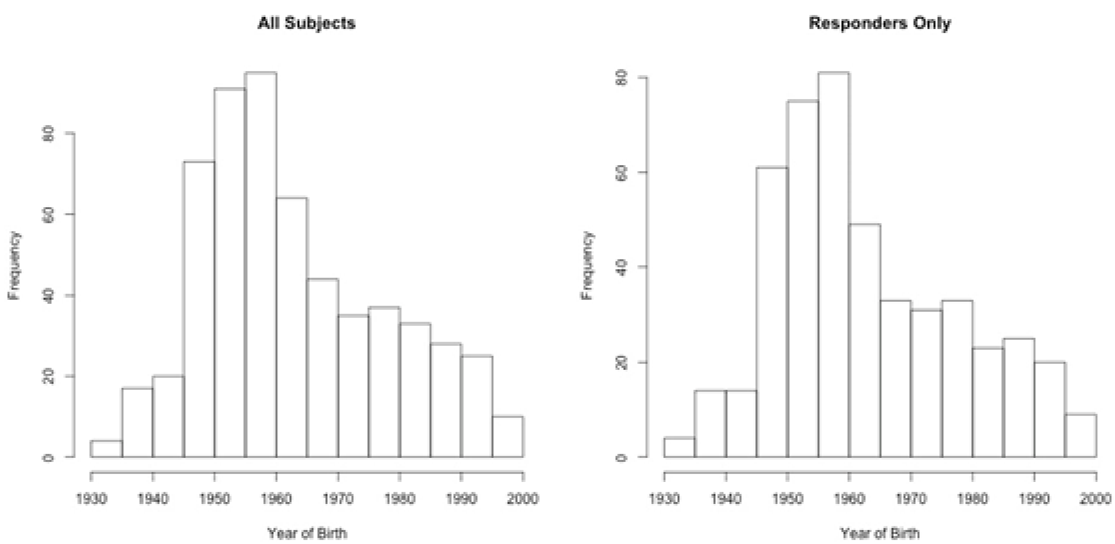


Figure 1 - Distribution of birth year of recruited sample

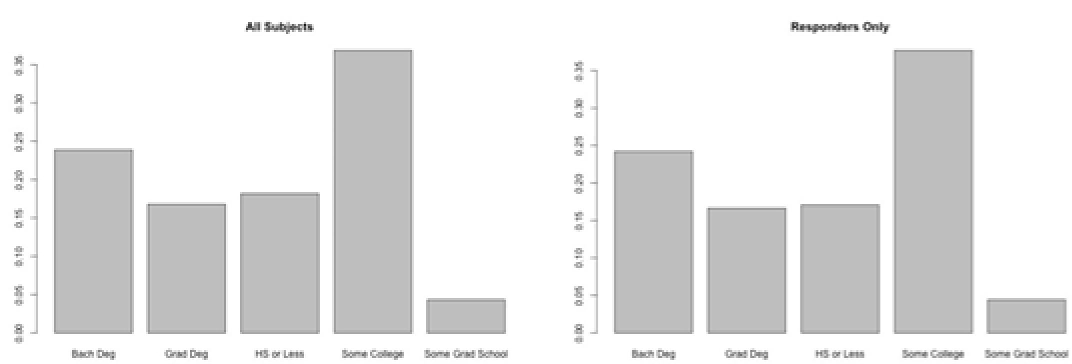


Figure 2 - Distribution of education level of recruited sample

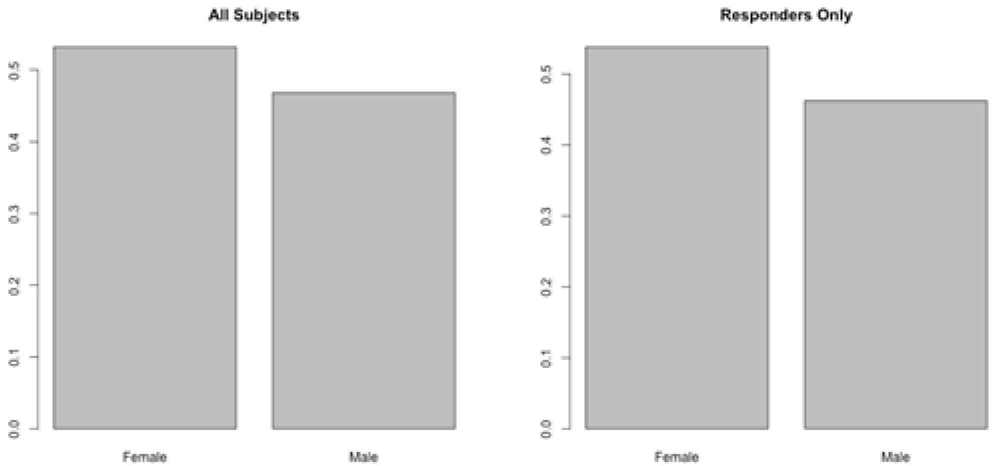


Figure 3 - Distribution of gender of recruited sample

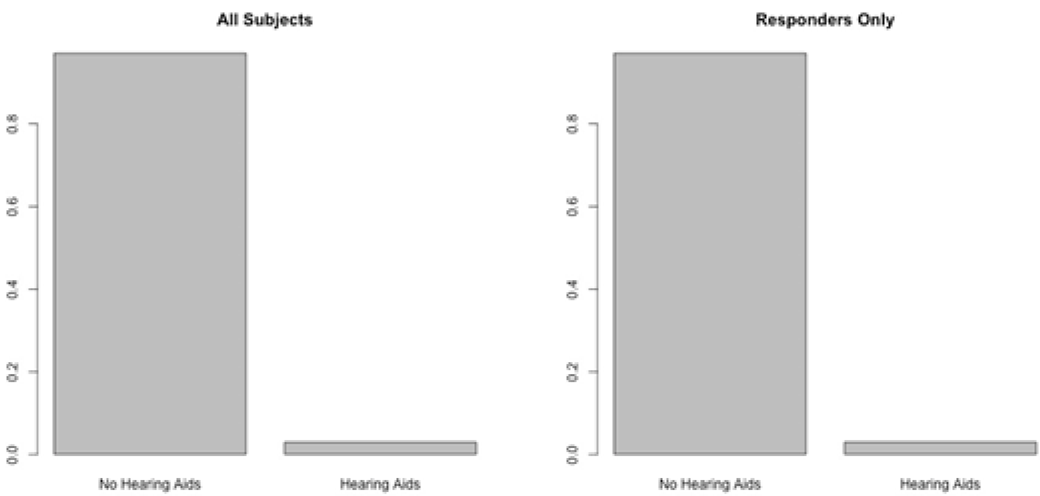


Figure 4 - Distribution of hearing aid status of recruited sample

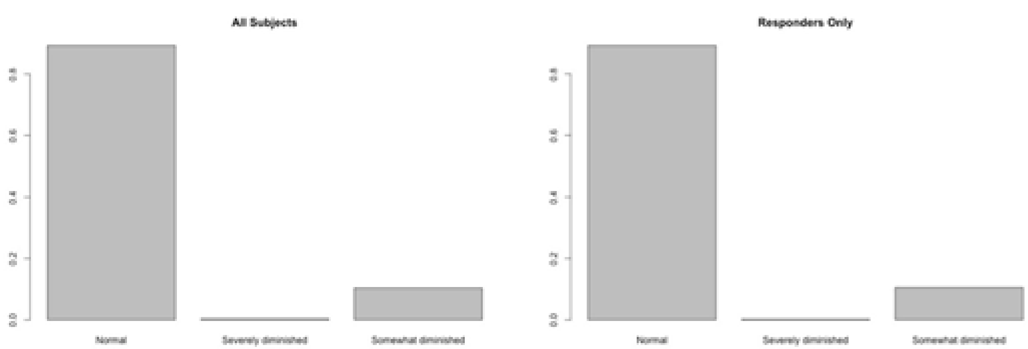


Figure 5 - Distribution of hearing level of recruited sample

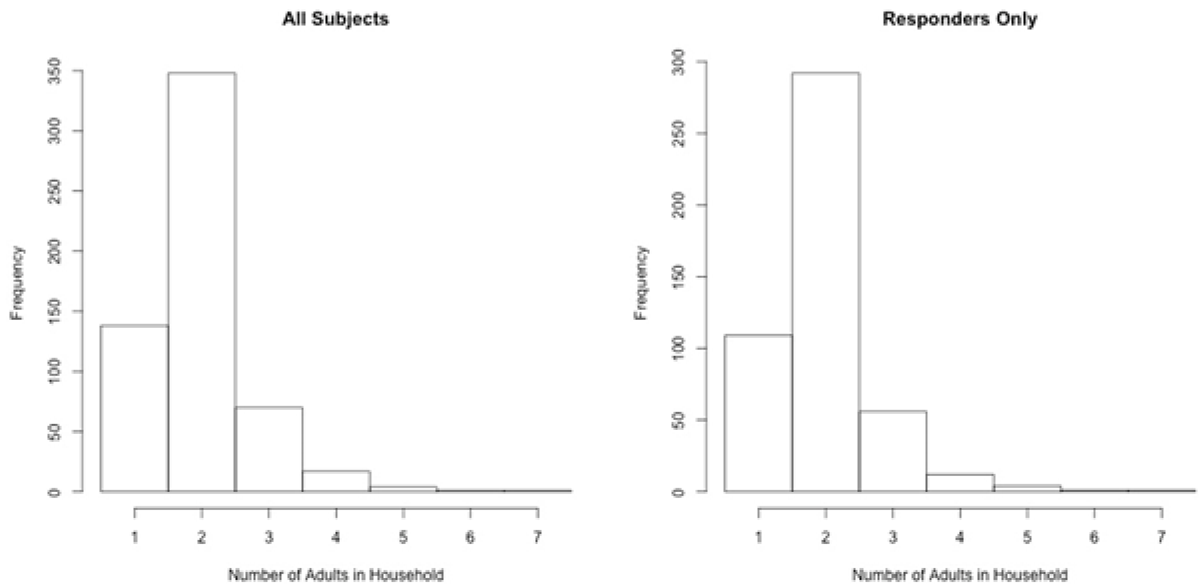


Figure 6 - Distribution of number of people in households of recruited sample

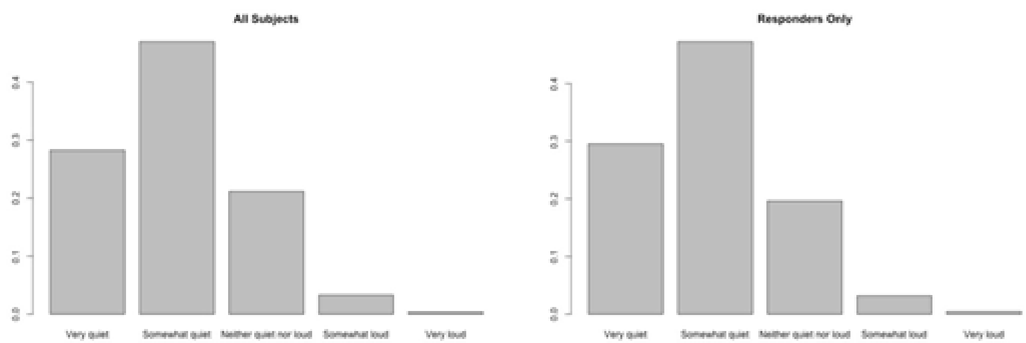


Figure 7 - Distribution of perceptions of household noisiness of recruited sample

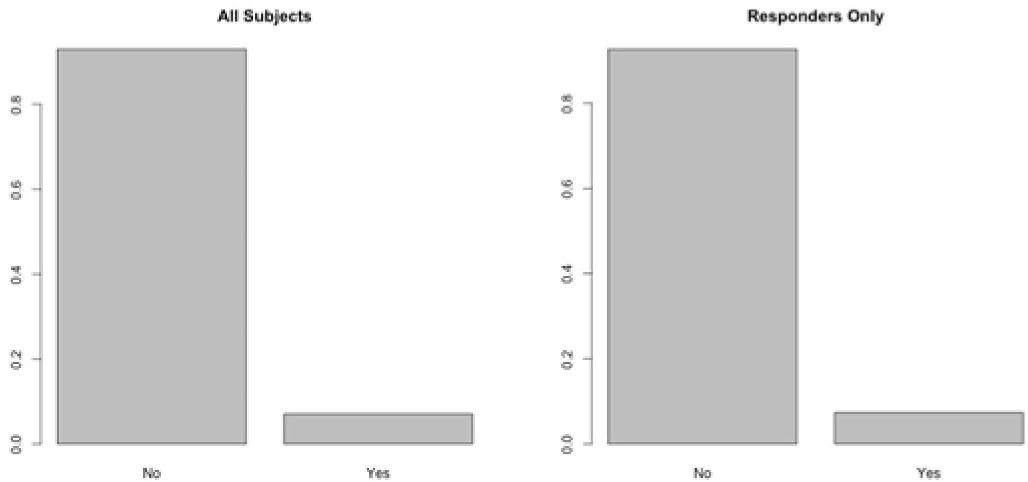


Figure 8 - Distribution of whether children under age 6 live in households of recruited sample

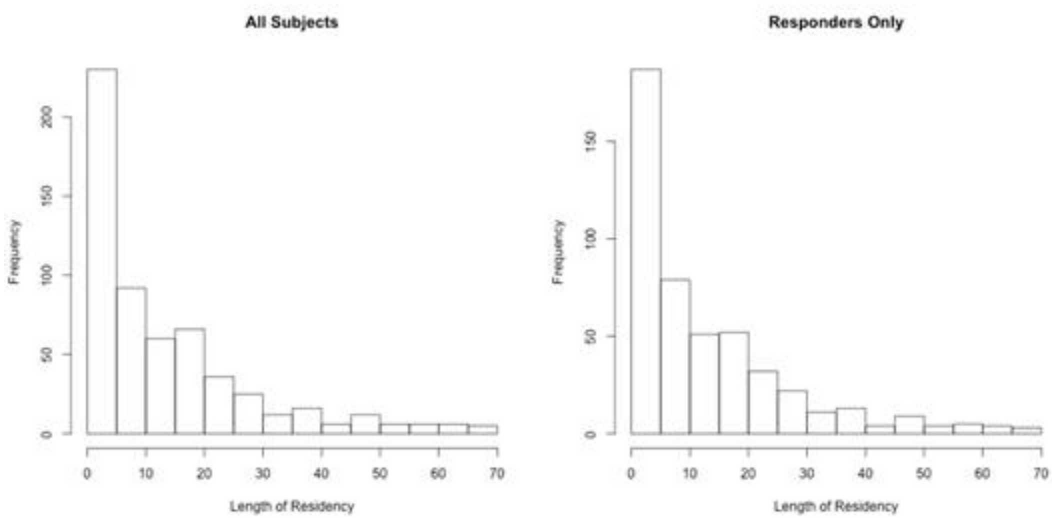


Figure 9 - Distribution of length at current residence of recruited sample

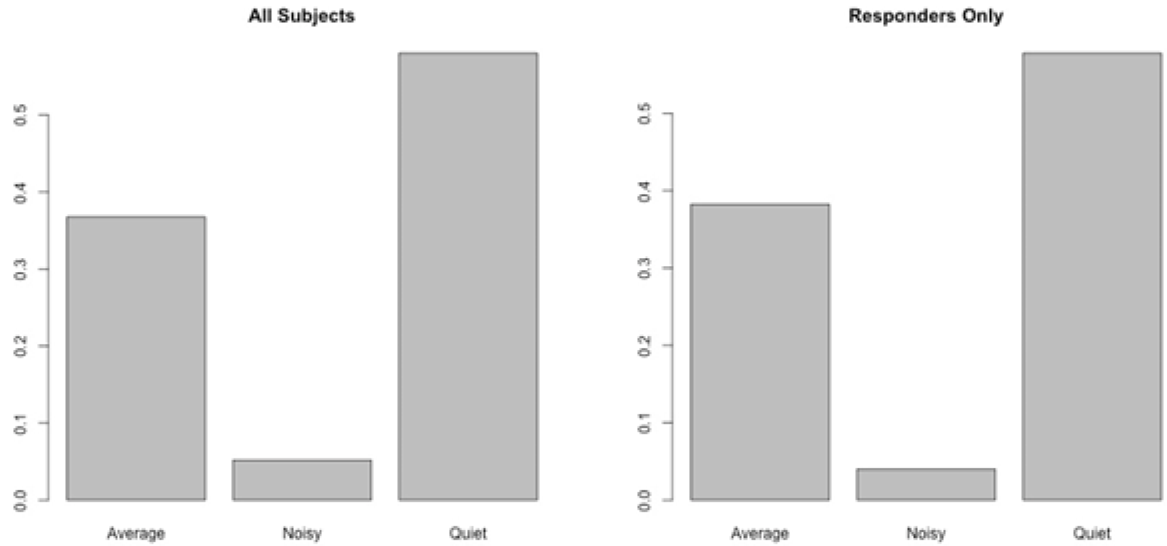


Figure 10 - Distribution of perceptions of neighborhood noisiness of recruited sample

Respondent Perception of Ability to Habituate to Noise

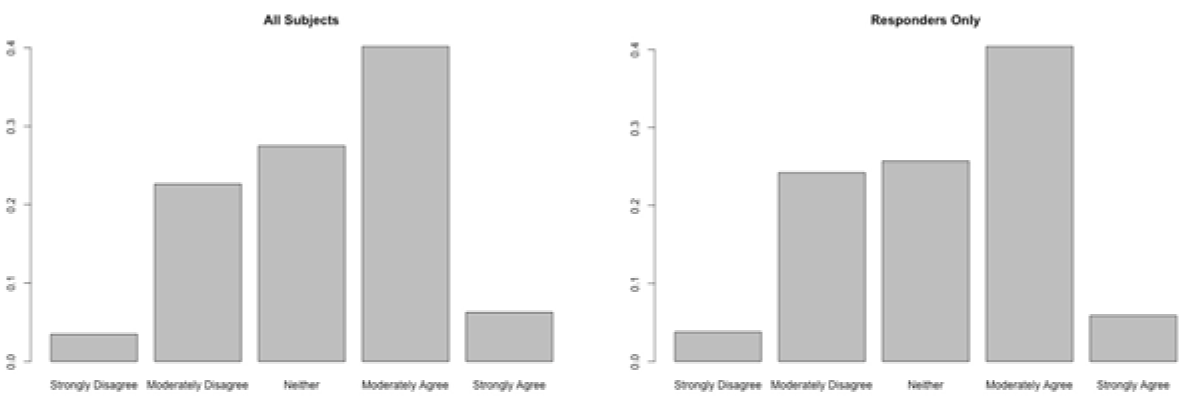


Figure 11 - Distribution of responses to "people have a hard time getting used to noise" for recruited sample

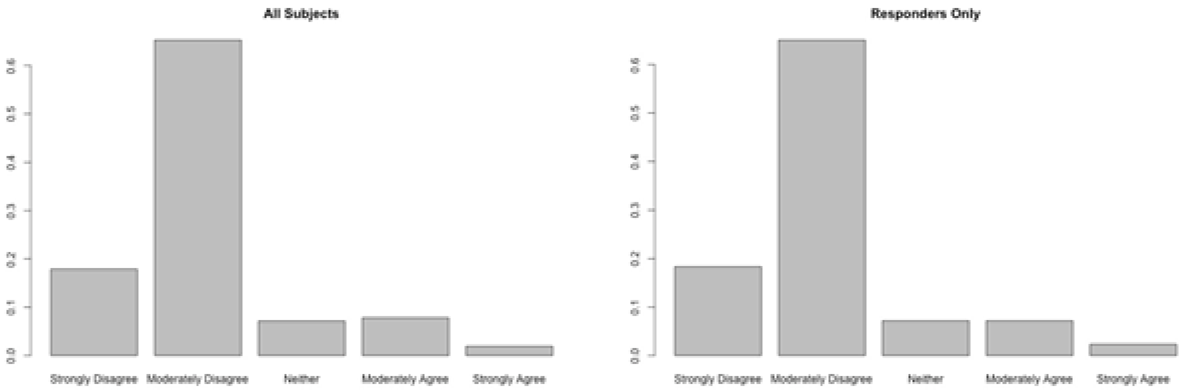


Figure 12 - Distribution of responses to “with time most people adapt to noise” for recruited sample

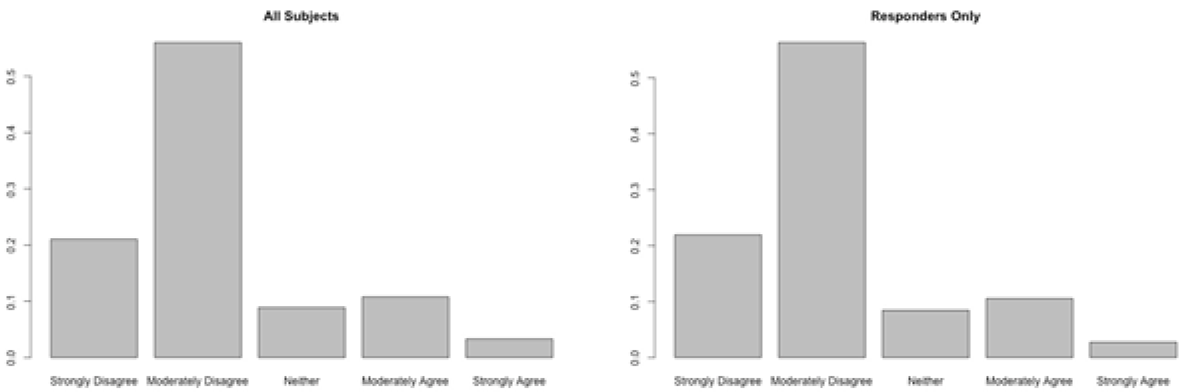


Figure 13 - Distribution of responses to “with time I can adapt to noise” for recruited sample

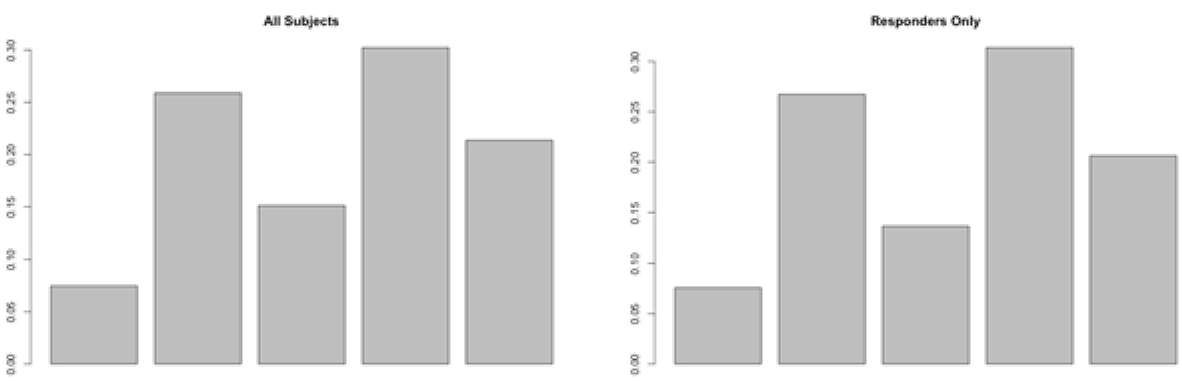


Figure 14 - Distribution of responses to “with time I can get used to even the loudest noise” for recruited sample

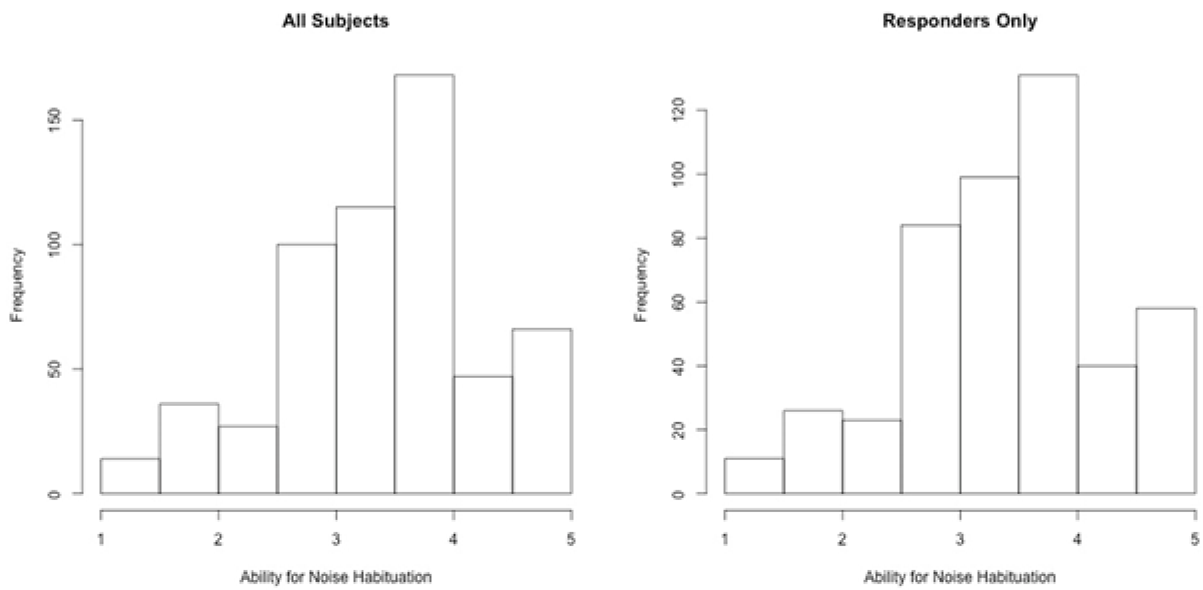


Figure 15 - Distribution of calculated ability to habituate scale for recruited sample

Respondent Noise Sensitivity Scale

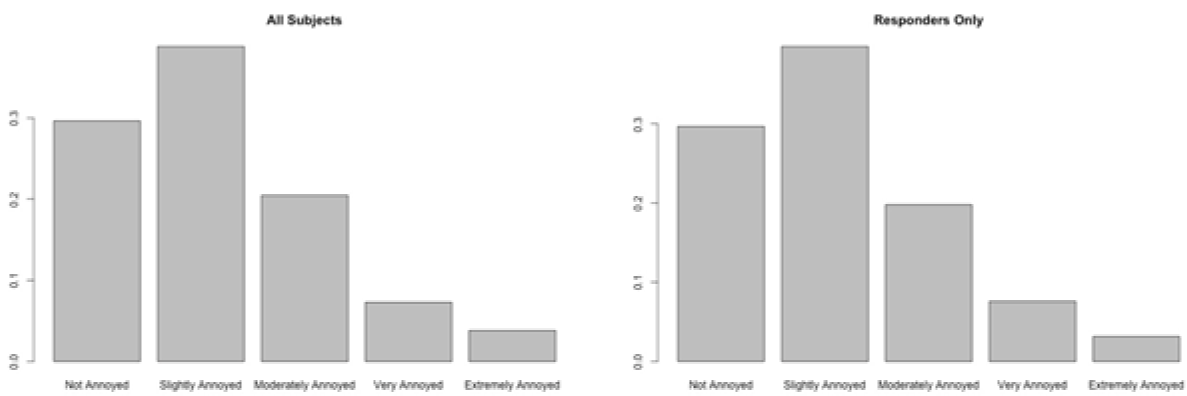


Figure 16 - Distribution of responses to annoyance with barking dogs for recruited sample

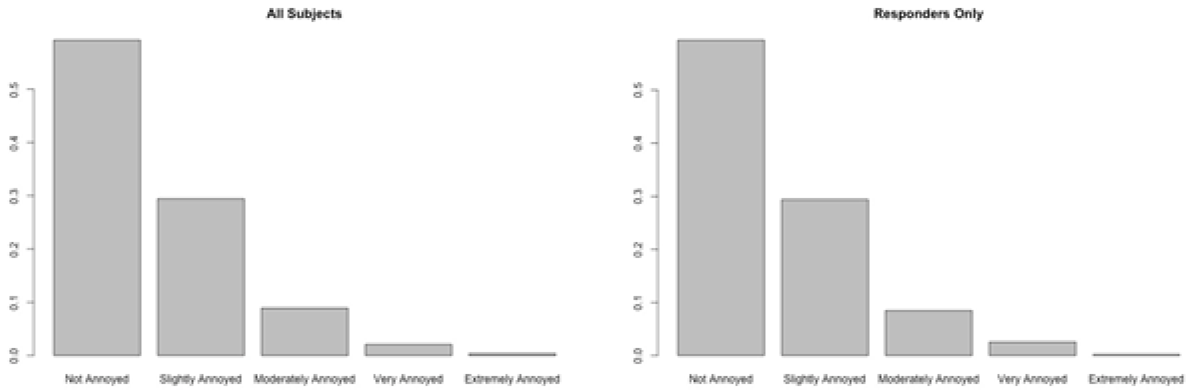


Figure 17 - Distribution of responses to annoyance with thunder for recruited sample

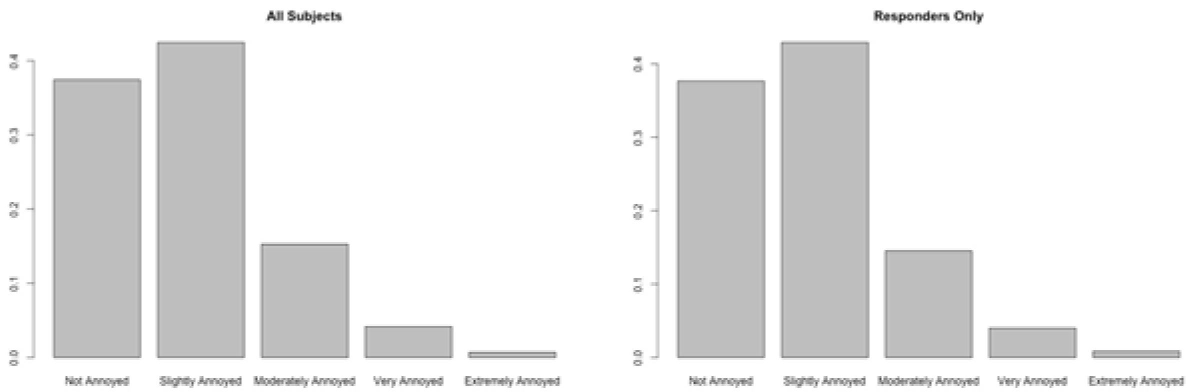


Figure 18 - Distribution of responses to annoyance with street traffic for recruited sample

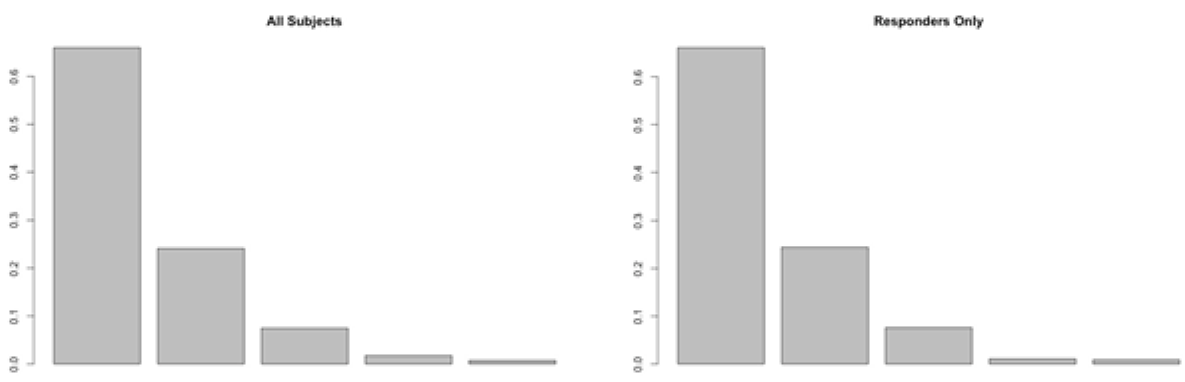


Figure 19 - Distribution of responses to annoyance with commercial aircraft for recruited sample

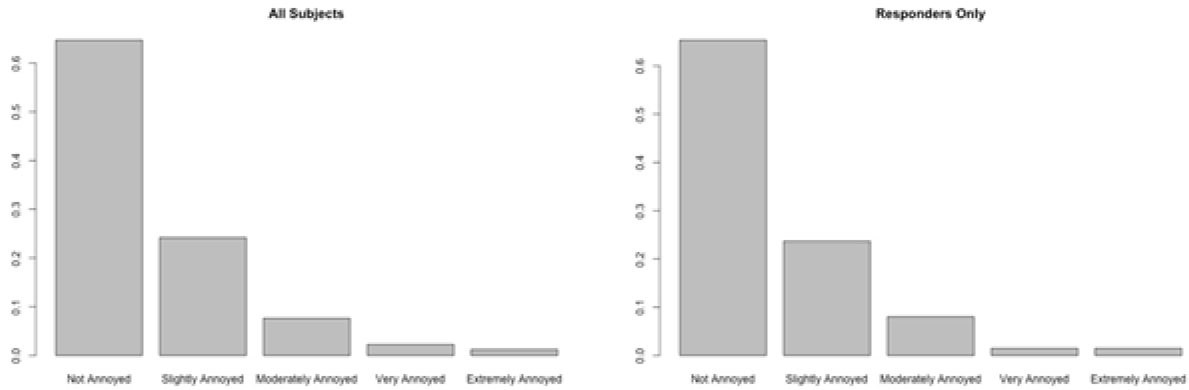


Figure 20 - Distribution of responses to annoyance with military aircraft for recruited sample

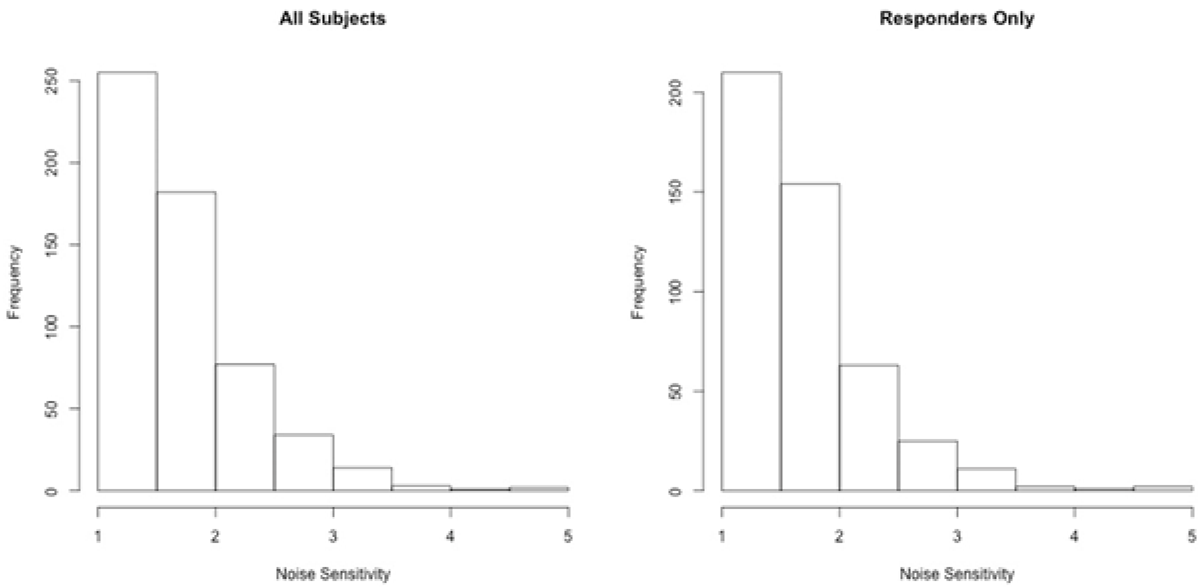


Figure 21 - Distribution of calculated noise sensitivity scale recruited sample

M. PCBoom Best Practices

The following pages provide Appendix M. This appendix file is provided separately from the main body of the report.

Memorandum

U.S. Department

of Transportation

Subject: QSF-18 PCBoom / PCBurg best practices and lessons learned

Date: 08 April 2019

From: Robert Downs, Volpe V-324

Project: VPH9

To: Jonathan Rathsam, NASA and Robert Hunte, APS

In the time leading up to the QSF-18 tests and during subsequent data analysis, a number of investigations were made into various facets of PCBoom modeling. This document summarizes those investigations and suggests best practices and lessons learned for footprint modeling and data analysis using the PCBoom suite of tools.

Increasing footprint resolution with TADVNCE

Footprint modeling in support of test planning relied in part on a template dive maneuver, whose trajectory file comprised points at 0.25 sec spacing. For isopemps corresponding to times late in the maneuver, the spatial resolution of ground intersection points became relatively low. To produce a better resolved footprint for analysis, the template dive trajectory file was supplemented with TADVNCE statements. This PCBoom feature projects the aircraft trajectory forward from the current position by a specified time. Multiple TADVNCE lines can also be used in succession to further subdivide a trajectory file. Note that when editing a trajectory file care must be taken to maintain a consistent format (e.g. use spaces instead of tabs) to avoid PCBoom run errors. A comparison of footprints showing the end result is given below.

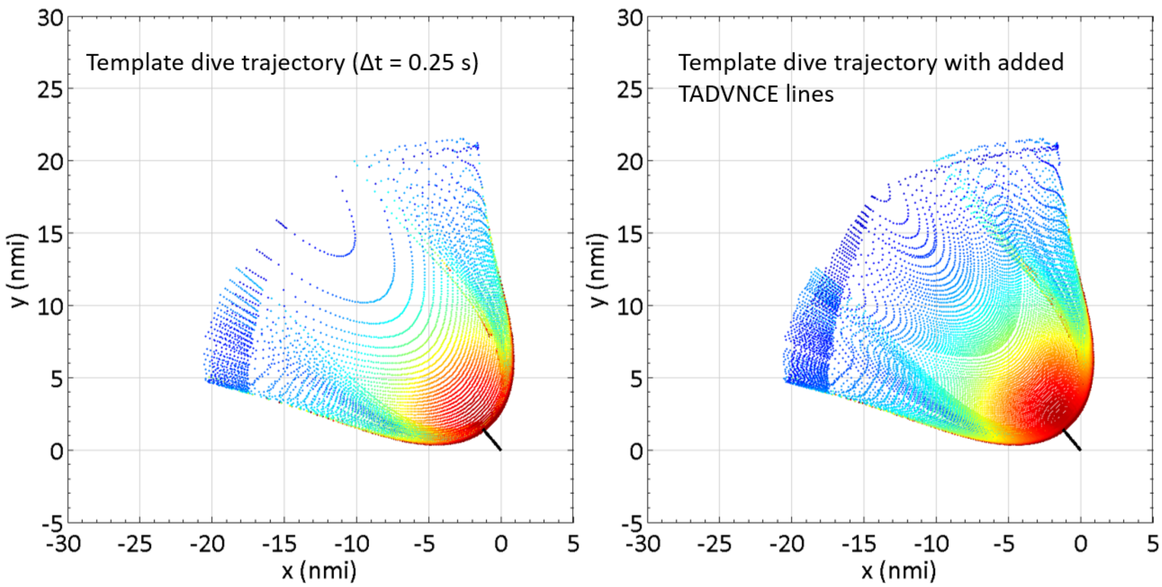


Figure 1. Comparison of a footprint modeled with template dive trajectory, and the same trajectory with TADVNCE statement used at intermediate points to increase footprint resolution.

Effects of aircraft weight on ground metrics and signatures

The effect of aircraft weight on starting signature, and hence, ground metrics was investigated using aircraft weight information from the AFRC pretest. Comparing the range of aircraft weights at start of dive maneuvers, it was observed that aircraft weight could be as much as 5,000 lb different from the first pass to the last pass of a flight. These values are summarized below.

	FLT01	FLT02	FLT03	FLT05	FLT07	FLT09
Pass 1	35.3	34.9	35.1	34.8	34.7	35.2
Pass 2	31.1	31.8	32.7	30.1	30.2	30.8
Pass 3	-	30.0	30.3	-	-	-

Table 1. Aircraft weights (thousands of pounds) by dive from AFRC pretest

Using template dive and a measured November atmospheric profile, Burgers equation propagation modeling was completed for a range of aircraft weights from 30 – 35 klb. For a waypoint 1 dive, the modeled loudness at noise dose design site 1 varied as much as 1.1 dB.

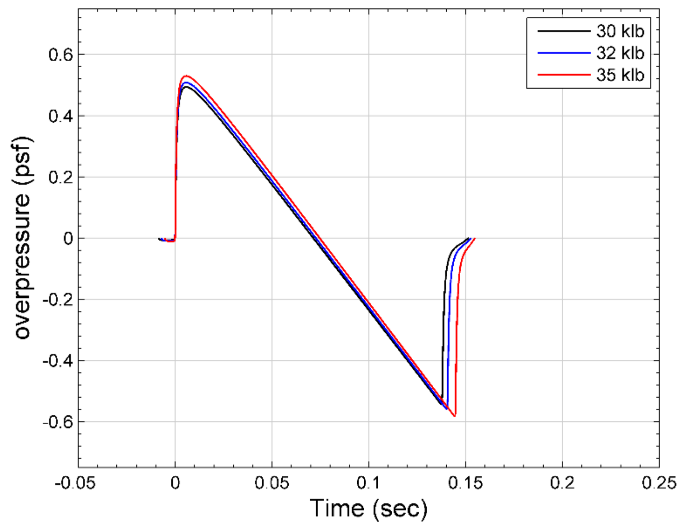


Figure 2. Comparison of ground signatures modeled using different aircraft weights

Aircraft weight	PL
30 klb	90.9 dB
32 klb	91.6 dB
35 klb	92.0 dB

Table 2. Comparison of loudness metrics with aircraft weight for an example LBDM ray.

Examining the ground signatures, it appears that a result of increasing aircraft weight is to increase the peak overpressure at the ground. Given this variability, a best practice is to include accurate weight information whenever possible. Two notes:

1. If weights are included in the trajectory file, NEWLOAD statements are needed
2. If weight is included in a Carlson mode input statement in a PCBoom .dat file, there is a misprint in the PCBoom 6.6 manual: the order of aircraft weight and aircraft length are reversed.

PCBoom 6.6 manual has weight and aircraft length columns reversed

Table 4-24. MODE / CARLSON / ACNAME Keyword Format Description

Line	Column	Max Length	Variable Name	Description
1	1-8	8	actype	Vehicle name corresponding to one of the pre-programmed vehicles in Table 4-23.
	13-17	5	IUN	IUN specification of a different Carlson curve from Table 4-21. (Optional)
	18-27	10	WT	Vehicle weight specification. (Optional)
	28-37	10	AL	Vehicle length specification. (Optional)
	38-47	10	THR	Vehicle Thrust (klb). (Optional)
	48-57	10	DRAG	Vehicle Drag (klb). (Optional)

This example input statement is correct: F-18 with AL = 56 ft, WT = 32.2 klb

```
MODE
CARLSON
ACNAME
    F-18     5         56.        32.2
```

Figure 3. Example input file statement showing correct order of aircraft weight and length (bottom)

Propagation modeling with PCBurg

There are some parameters in PCBurg that can be changed to adjust propagation modeling including the sampling rate, anti-Gibbs filtering, and relative humidity (the latter option gives the possibility to use a constant relative humidity profile). A sampling rate of 51.2 kHz (command line option SR3) is recommended. A higher rate is available (102.4 kHz) though the run time is significantly increased and tests with LBDM rays show a difference of only 0.2-0.3 PLdB.

The use of anti-Gibbs phenomenon filtering is recommended to alleviate instabilities or numerical artifacts that can arise in the pressure signature during propagation modeling. Instabilities usually appear either as Gibbs phenomenon spiking at peaks, or as high frequency oscillations. Filtering is invoked as command line argument “UN”. The figure below shows how a LBDM ground signature compares when filtering is and is not used.

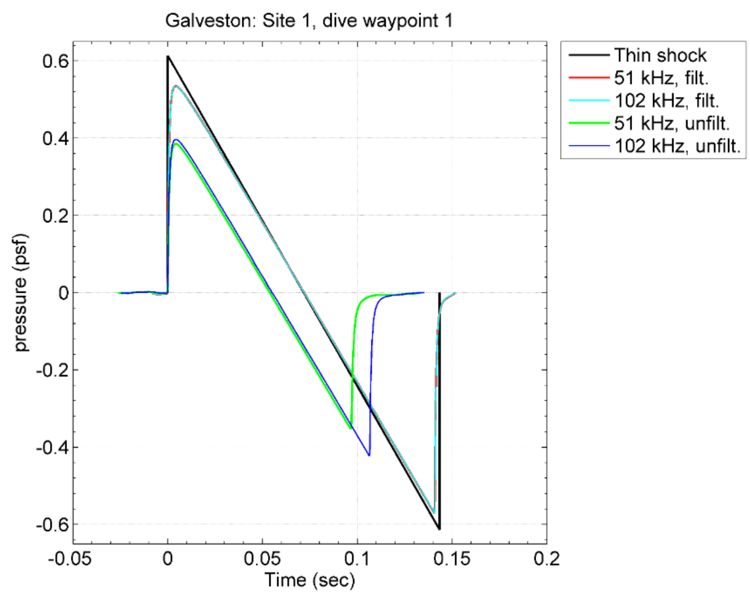


Figure 4. Comparison of Anti-Gibbs phenomenon filtering effects on ground signatures

The most significant source of ground metric level differences is the use of an accurate relative humidity profile. PCBurg can use RH profiles in .age input files, provided that the original atmospheric data read by FoBoom contained relative humidity profiles. Alternatively, PCBurg accepts a command line option to use a constant RH value. In the absence of an RH profile, one could this option to bracket ground metric values. To demonstrate this, propagation of a single ray was modeled using a measured atmospheric profile, and also with RH0 and RH100 options. The ground-doubled PL levels were:

Relative humidity	PL
0% (constant)	87.7 dB
Measured (11/30/07)	91.0 dB
100% (constant)	94.1 dB

Table 3. Comparison of relative humidity effects on loudness metrics for a LBDM case.

Comparing ground signatures in the plot below, it is clear that including a relative humidity profile in the atmospheric input has a substantial effect on ground metrics.

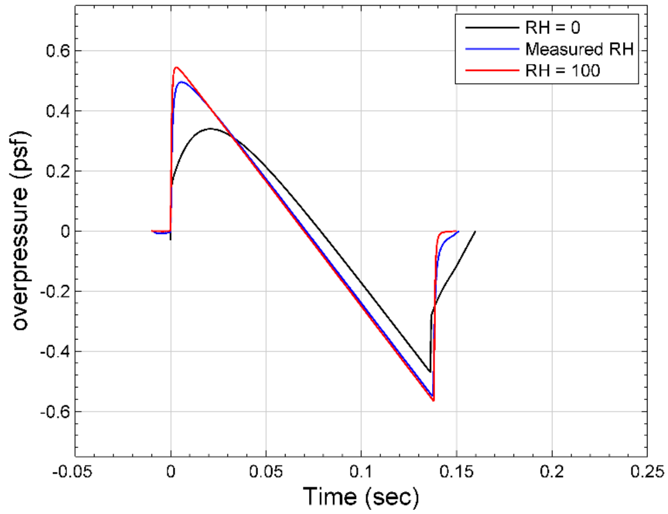


Figure 5. Effect of relative humidity on ground signatures from a LBDM

Using secondary PCBoom output files for additional analyses

Among the different types of PCBoom output files, there are two in particular that are useful in external analysis: PCBFOOT .asc file and WCON .pdx files. These files are described in the PCBoom user manual and a few additional undocumented pieces of information are given here. Both files contain, among other things, (x,y) ground coordinates and overpressure levels so a footprint can be imported into other platforms. The data formats can be discerned for the most part on inspection; in both file types, there is a column of integers on the far right that signifies boom type. Numbers in this column correspond to:

Far right column value	Boom type
-1	Missing signature
0	None
1	Carpet boom
2	Maximum focus boom
3	Post-focus boom

Table 4. Boom type codes in PCB .asc files and WCON .pdf files

An additional piece of information available in the .asc file (but not in the .pdx file) is the aircraft time associated with each isopemp. This can be used, for example, along with phi and (x, y) to form a ground-referenced lookup table of starting ray information (T_{ac}, phi) to build PCBurg batch analyses.

Large ray tube areas in FOBoom 6.7 output

In the course of analyzing QSF-18 as-flown data, it was observed that in rare cases that values in the ray tube area column in FOBoom .age files could overrun the allotted width. Specifically, values larger than 999,999 cause this field to merge with the RH column to the left. This was only apparent when trying to run PCburg on an affected ray. To remedy this problem, a modification to FOBoom was made which reduced the numerical precision of this field from %13.6f to %13.4f. This Volpe version of FOBoom 6.8b was used to produce .age files without this problem. However, it would also be possible to manually edit .age files by removing the last two digits from each row and adding spaces between RH and Area columns, though that method would be labor intensive.

```
528705 14000.  1246.40698  1074.16504   87.183029    0.915661    0.543342   54.45 519410.812500
528706 13000.  1296.56982  1079.67114   90.718750    0.928845    0.545534   71.77 519400.437500
528707 12000.  1347.52026  1082.58997   94.470718    0.930383    0.547804   82.85 539608.500000
528708 11000.  1400.19336  1087.20947   98.231026    0.911022    0.549970   66.62 586343.500000
528709 10000.  1452.37170  1085.94385  101.694099    0.865894    0.551818   33.07 692250.750000
528710  9000.  1510.17151  1085.40210  104.996101    0.863308    0.553456   32.81 707134.000000
528711  8000.  1572.01880  1087.08154  108.943878    0.926455    0.555428   56.13 624331.000000
528712  7000.  1632.09436  1087.13538  113.169846    0.885334    0.557509   73.68 719691.562500
528713  6000.  1692.13611  1087.93005  116.652458    0.801804    0.559026   65.11 945085.125000
528714  5000.  1755.39343  1089.09082  119.527817    0.763472    0.560137   51.841113883.000000
528715  4000.  1824.56042  1083.63892  122.314285    0.745163    0.561144   73.971184184.000000
528716  3000.  1895.26514  1080.57593  125.159706    0.755576    0.562128   95.361218565.250000
528717  2000.  1969.93799  1085.57666  127.899857    0.754362    0.563043   98.571262113.250000
528718  1000.  2048.14111  1091.51978  130.780365    0.781793    0.563984   85.511208236.125000
528719     3.  2131.02148  1097.67529  134.088455    0.848297    0.565085   69.111029716.187500
528720 -2000.  2131.02148  1097.67529  134.088455    0.848297    0.565085   69.111029716.187500
528721
```

Figure 6. Example of output errors in a .age file; this was corrected in FOBoom 6.8b

N. Locating Participants at Time of Sonic Thumps

The following pages provide Appendix N. This appendix file is provided separately from the main body of the report.

Memorandum

U.S. Department
of Transportation

Subject:	Methodology for Locating Participants at the Time of Sonic Thump Events	Date:	05 April 2019
From:	Gary Baker, Volpe V-322		*Project: VPH9*
To:	Jonathan Rathsam, NASA and Robert Hunte, APS		

1.1 Introduction

This document describes the data processing and GIS analysis used to obtain each of the participant locations at the time of each sonic thump event. Due to the variation in metric values across the footprint from the F-18 Low Boom Dive maneuver utilized at the QSF-18 tests, and because the intent of this analysis was to test procedures and protocols, it was important to locate participants as accurately as possible. During the development and execution of the analysis procedures using the QSF-18 analysis, notes and lessons learned were documented and referred to as NLL-# and are listed in Appendix 1.

1.2 Locating Participants

Participant's home and work addresses were provided in the "Id and addresses" sheet of the "Daily Summary Nov 2018 labels.xlsx" Excel file. This appears to be a subset of information also found in the "Consentbackground Nov 2108 labels with addresses no PII.xlsx" Excel file. Participant identifiers and addresses from the two different sources were not cross-checked and the decision was made to use the data from "id and addresses" because it had 500 participants [NLL-1].

To map home and work locations the addresses must be converted into a latitude and longitude values through the process of geocoding. There were a number of inconsistencies in the data that needed to be cleaned up prior to geocoding. For example the location was referred to with the common name "assisted living home" or "23rd St Bookshop" rather than the physical address, or occasionally fields such as the city or zip code had a typographical errors such as Galvwston and Tikiisland. Home addresses

were cleaned up in a similar way [NLL-2].
In a number of cases Google Maps was used to search for an address to confirm the change. Updates to the original addresses were only made when there was reasonable confidence that the change to the address was correct. Out of the 500 participants, updates to both home and work addresses were made for 34 participants, updates to only the home address were made for 22 participants, and updates to only the work address were made for 25 participants. There were 13 home addresses and 8 work addresses that were not useable (e.g. no address provided). Once the address data had been cleaned the ArcGIS World Geocoding Service was used through Esri's ArcGIS Pro Software to geocode the addresses. [NLL-3].

In addition to home and work addresses, other locations were provided for many single event surveys when the participant wasn't at or near home. There were 396 such unique locations in the dataset. Unfortunately these addresses are almost completely freeform and many were difficult or impossible to locate. Of the 396 unique locations, 299 could be located while 97 could not be located. A significant number of the locations that ultimately could be located required research and cleaning, for example "l.a morgan school 36th street" was updated to the official address of the LA Morgan Elementary School which is "1410 37th st". Of the 97 that couldn't be located, some could be roughly located but not with enough precision to assign a reasonable latitude and longitude (e.g. midtown Galveston) while others were completely unusable (e.g. driving to work).

Table 2 illustrates the occurrences of combinations of 4 data elements related to locating the participants for the single event records. "lat/lon provided" and "Other Location Provided" are derived Boolean fields based on the existence of lat/lons or "somewhere else" respectively. Over 71 percent of the records fall into the "Map Shows Correctly" = True and "lat/lon provided" = True category. Over 15 percent of the records indicate the location to be home and over 6 percent of the records indicate the location to be work. All occurrences of home and work use the participant's geocoded home or work address respectively despite some home or work records having a lat/lon [NLL-4].

Map Shows Correctly	Lat Lon Provided	Location	Other Location Provided	
yes	True	null	False	8,462
	False	null	False	163
no	True	home	False	531
		work	False	283
		elsewhere	False	8
			True	263
		null	False	9
	False	home	False	38
		work	False	50
		elsewhere	True	22
no map displayed	True	home	False	17
		work	False	3
		elsewhere	False	3
			True	3
		null	False	2
	False	home	False	1,235
		work	False	428
		elsewhere	False	22
			True	238
		null	False	18
null	True	null	False	6

Table 1 - Combinations of Elements Related to Locating Participants for Single Event Records

1.3 Bringing it all together

Once all addresses have been manually cleaned and located where possible, the next step is to bring all of the data elements together for further processing and analysis. A Python script was developed to do this. The script begins by reading all necessary source data from Excel and text files (i.e. geocoded addresses) into in-memory data structures. This takes the data from Excel, which in some cases is organized in a way that makes it very difficult to work with, and puts it in a format that makes it easy to examine, debug, and analyze [NLL-5].

The next step was to examine each participant location at the time of each sonic thump event. For each of the 26,000 unique thump/participant combinations, the following is passed into the "process participant for thump" function:

- The information about the particular thump event (date, time).
- The information about the participant, including the participant's geocoded home and work addresses.

- Any single event survey records for that participant on the day of the thump event being processed, including “other locations”.
- The daily summary, if it exists, for that participant on the day of the thump event being processed.
- Geocoded “other locations” for lookup if necessary.

With this data, the following logic is used to locate a participant at the time of the thump. Each different way a location is determined, or cannot be determined, is assigned a location assignment type code.

1. The first step is to determine if the participant recorded any single events for the day.

   If there were single events recorded, then the closest single event within 20 minutes of the thump time was associated with the thump [NLL-6] and the location was determined using the following logic:

   - If that single event indicated that the map showed correctly and the latitude and longitude were non-zero, then the recorded latitude and longitude was used [location type 1].
   - Otherwise, if the location indicated was home or work then the coordinates for the respective geocoded address were used [location types 2 and 3].
   - Otherwise, if the location indicated was “other” and the address was successfully geocoded then the coordinate for the geocoded “other” address were used [location type 4].
   - Otherwise no location could be determined [location type 5].

   If there were single events but none within the 40 minute time window, 20 minutes on either side of the thump, then:

   - If the daily summary indicated the participant was at home or at work at the time of the thump then the corresponding location was used [location types 6 and 7].
   - If the daily summary didn’t indicate they were at work or home at the time of the thump then no location could be assigned [location type 8].
   - If there was no daily summary then no location could be determined [location type 9]

2. If the participant had no single events on the day of the thump and there was a daily summary then the logic used is similar to that when there are single events in the day but none can be associated with the thump event:
    - If the daily summary indicated the participant was at home or at work at the time of the thump then the corresponding location was used [location types 10 and 11].
    - If the daily summary didn't indicate they were at work or home at the time of the thump then no location could be assigned [location type 12].

3. If there were no single events and no daily summary on the day of the thump event then nothing could be done for the particular thump/participant combination [location type 13]

This processing script creates a results file with 26,000 rows, one for each thump/participant combination. The main elements of the file include the thump_id, the participant id, the lat/lon of the person at the time of the thump (when possible), a determination for whether it was heard or not, and the location assignment code.

Table 3 describes the different location assignment codes and shows the occurrences of each along with information on results with and without valid lat/lons. It should be noted that each location type code either does or doesn't have lat/lons with relatively few exceptions. For example, location type code 2 mostly results in valid lat/lons with the exception of 8 participant/thump combinations, something that occurs due to one or more address which couldn't be located.

location assignment code	Location Assignment Description (SE = single event, DS = daily summary)	participant/thump combinations with valid lat/lons	participant/thump combinations without lat/lons
1	Matched SE with lat lon (NOTE: some of these lat lons are very far away)	5,111	0
2	Matched SE, at home	1,113	8
3	Matched SE, at work	418	0
4	Matched SE, somewhere else	190	0
5	Matched SE, undetermined location	0	285
6	Have SEs for day but no time match, DS indicates home at time of event	2,369	25
7	Have SEs for day but no time match, DS indicates work at time of event	989	13
8	Have SEs for day but no time match, DS indicates not at home or work	0	1,215
9	Have SEs for day but no time match, and no DS fall back	0	3,242
10	No SEs for day but DS indicates at home	2,740	28
11	No SEs for day but DS indicates at work	1,721	25
12	No SEs for day and not locatable from DS	0	1,498
13	Neither SEs nor DS	0	5,010
	TOTAL	**14,651**	**11,349**

Table 2 - Location Types and Frequencies

Appendix I - Notes and Lessons Learned

NLL-1 – The same data shouldn't appear in different places when handing off study results to multiple teams and researchers. It would be clearer to have one file with the final information for the participants.

NLL-2 – Cleaning addresses is manually intensive and potentially error prone. More automated checking of addresses at the time of input is highly suggested, especially if significantly more participants are to be used in future studies. Additionally, while the data was supposed to be without PII, there was at least one case where the address included "ATT:" (i.e. Attention) along with a name.

NLL-3 – All work and home addresses should be geocoded prior to acceptance into study. Presumably no one should be missing a home address. If a work address is missing there should be some indicator as to why (e.g. retired, unemployed) to differentiate cases where the data wasn't provided.

NLL-4 – Odd combinations of location related variables sometimes seem to contradict each other and make it difficult to decide how to handle them. An example of this would be when the value for "map shows correctly" = 'no' but a lat/lon and an address is included. Does this mean that the lat/lon value is not good? If that's the case then it shouldn't be included in the data set.

NLL5 – Having the data organized in simple relational structure would make it much easier to work with and make analyses less error prone. The Excel based daily summary file format is particularly awkward. Its sparse structure requires complicated logic to extract the reported times at home and at work, something that would not be needed if the data resided in a simple relational structure. Additionally, a relational data approach would remove the difficulty associated with having a code book with separate labels and variables sheets.

NLL-6 – While unique participant/thump combinations are processed, this does not prevent the possibility of the same single event being associated with two different thump events for the same participant.

NLL-7 – "Did you hear any sonic thumps today?" in the daily summary could lead to errors.
For example, if the participant reported having heard some single events on a given day and didn't submit single events for others, then it is very possible that the thumps for which single events weren't submitted weren't heard. Consulting the daily summary, which will have a value of "yes" for "Did you hear any sonic thumps today?" could result in unheard thumps being converted to heard thumps.

O. Calculating Metrics at Participant Locations

The following pages provide Appendix O. This appendix file is provided separately from the main body of the report.

Memorandum

U.S. Department

of Transportation

Subject:	QSF-18: Method for determining metrics at participant locations	Date:	05 April 2019
From:	Robert Downs and Juliet Page, Volpe V-324	Revised:	19 July 2019
To:	Jonathan Rathsam, NASA and Robert Hunte, APS		*Project: VPH9*

Input data

This document provides a concise description of the methods used to estimate metrics at participant locations, based primarily on three sources of input data:

1. Measured metrics at monitor locations,
2. Participant locations at boom times, based on single event (SE) / daily summary (DS) response data,
3. Results of PCBoom / PCBurg footprint modeling using version 3 (received 29 November 2018) as-flown trajectory data and measured atmospheric profiles.

The measured metrics dataset contains levels calculated using 650 ms durations as well as 3000 ms durations along with corresponding ambient levels. For this analysis, both sets of metrics were used. Furthermore, minimum thresholds are placed on metrics relative to ambient levels: measured levels must have been at least 1 dB, 3 dB, or 5 dB above local ambient to be included in the analysis. Together, duration and ambient threshold criteria resulted in six complete sets of metrics at participant locations. For each event, the set of monitors whose metrics were above the ambient thresholds were considered the "usable" monitors for that event/metric combination. At least one usable monitor was required to determine metrics at participant locations. Note, however, that ambient levels calculated with 650 ms durations are not directly comparable with the longer duration 3000 ms metrics so those datasets are relatively insensitive to the ambient criterion. For example, in the 1 dB / 3000 ms dataset, all monitor signals passed the ambient check except one monitor on one event.

Survey response data in the form of single event response and daily summaries were used to determine participant locations and correlate those locations with specific booms. Geolocation analysis procedures are based on Table 1 with the specific details explained in more detail in the participant geolocation documentation.[1] Due to the varied nature of these data, several possible location assignment codes were defined to track the provenance of location data throughout the analysis. Metrics were determined for all locatable participant responses and further analysis could be conducted using for

[1] Volpe Memo "Methodology for Locating Participants at the Time of Sonic Thump Events", included as Appendix M to QSF-18 final report, or section 6.1.2 in final report

example, only single event response data. The following table describes how locations were determined and the corresponding location assignment codes.

Location assignment code	Location assignment description (SE = single event, DS = daily summary)	Latitude / longitude source
1	Matched SE, map showed correctly in survey	Lat./long. from response data
2	Matched SE, at home	Lat./long. from geocoded address
3	Matched SE, at work	Lat./long. from geocoded address
4	Matched SE, somewhere else	Lat./long. from geocoded address
5	Matched SE, undetermined location	None
6	Have SEs for day but no time match, DS indicates home at boom time	Lat./long. from geocoded address
7	Have SEs for day but no time match, DS indicates work at boom time	Lat./long. from geocoded address
8	Have SEs for day but no time match, DS indicates not at home or work at boom time	None
9	Have SEs for day but no time match, and no DS for location fall back	None
10	No SEs but DS indicates at home	Lat./long. from geocoded address
11	No SEs but DS indicates at work	Lat./long. from geocoded address
12	Not locatable from DS	None
13	Neither SEs nor DS	None

Table 1. Participant location match type summary

Note that not all addresses were locatable using geocoding; some addresses were incomplete or otherwise indeterminate. In those cases no latitude / longitude coordinates were available to determine metrics at participant locations.

Metrics calculated from modeled ground signatures in PCBoom 6.70 / PCBurg 4 were used to supplement measured metrics. For each event, PCBoom programs FOBOOM 6.70, PCBFOOT 6.66, and WCON were run using v3 as-flown trajectory data and v3 measured atmospheric profiles to model dive footprints. PCBoom input files were assembled into an archive for delivery to NASA.

Defining regions of interest

ASCII output from WCON describing levels within modeled footprints was used to investigate how regions inside and outside the modeled footprint correlated with measured signatures at monitor locations[2]. It was observed in some cases that measured signals outside the predicted footprint had characteristics like those of ground boom signatures and thus appeared to be within the actual realized footprint. To account for uncertainty in the actual locations of footprint edges, margins around the modeled footprints were developed through comparison with boom quality ratings. As part of the metric calculation process, each measured signature was examined and assigned a rating of 1-4 indicating that the signature:

[2] Footprint cutoff margin determination was based on FOBoom propagation and not PCBurg results, because only the locus of ground boom locations / cutoff locations was relevant for this purpose, not signature amplitudes or waveforms.

1. Could be clearly attributed to the aircraft and originated during the supersonic portion of the trajectory (“good”)
2. Appeared to have overlapping booms (“overlap”)
3. Had characteristics of both a boom and other features (“nasty”)
4. Appeared to be a rumble

Since quality rating 1 included signatures which did not strictly appear to be booms, an additional criterion was applied in footprint margin determination: overpressure at least 0.1 psf. Boom quality ratings for all measurements are shown in Figure 1 by event number. Considering these criteria, inspection of the relationship between notional downtrack margins and the number of additional signals with rating 1 enclosed by notional margins indicated that a downtrack margin of 2.9 nmi provided a compromise between monitor inclusivity and margin size. Figure 2 shows that relationship quantitatively. For a margin of 2.9 nmi, 30 measured signals across the events considered are included in the footprint margins. The margins would need to be extended by approximately 1 nmi to add another measured signal rated 1, and doing so would incorporate “rumble” measurements. Booms 48-52 (flight day 9) were characterized by high overpressures at cutoff and appeared to have fundamentally different margins; in those cases, a downtrack margin of 4.2 nmi was used. A similar approach was used for lateral margins: monitors within 0.5 nmi of modeled footprint edges typically had quality ratings 1 and met the overpressure criterion. An example of the boundaries of a modeled footprint and its margins is shown in Figure 2. For visual reference, an outline of the coastline is drawn in black together with an offshore area comprising oil rig locations and requested airspace (large trapezoid).

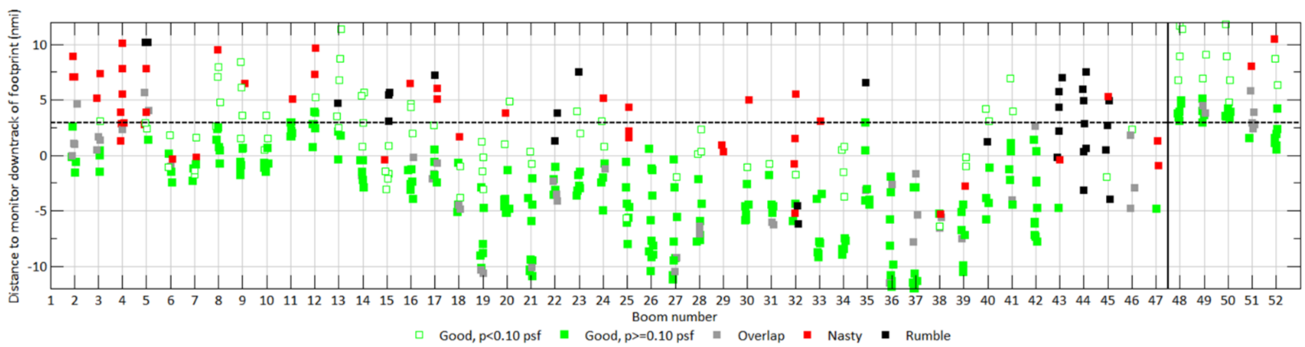


Figure 1. Comparison of boom quality rating with distance from footprint edge

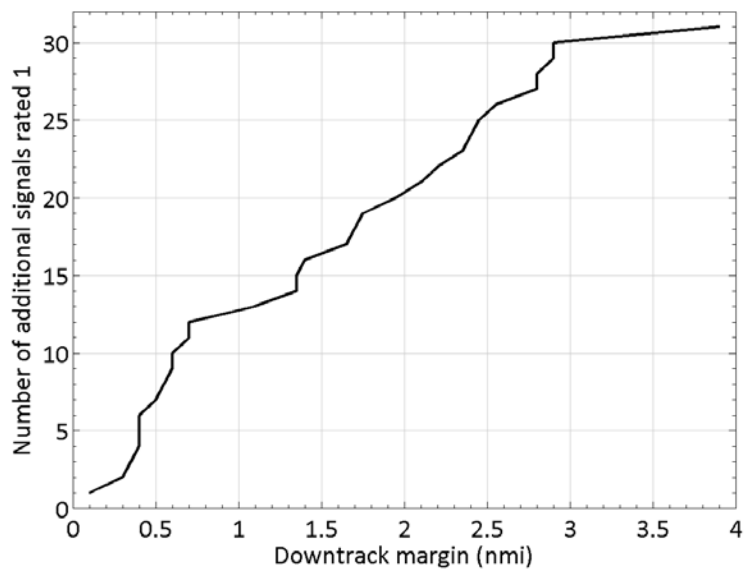


Figure 2. Relationship between monitor signals rated 1 and downtrack distances beyond modeled cutoff

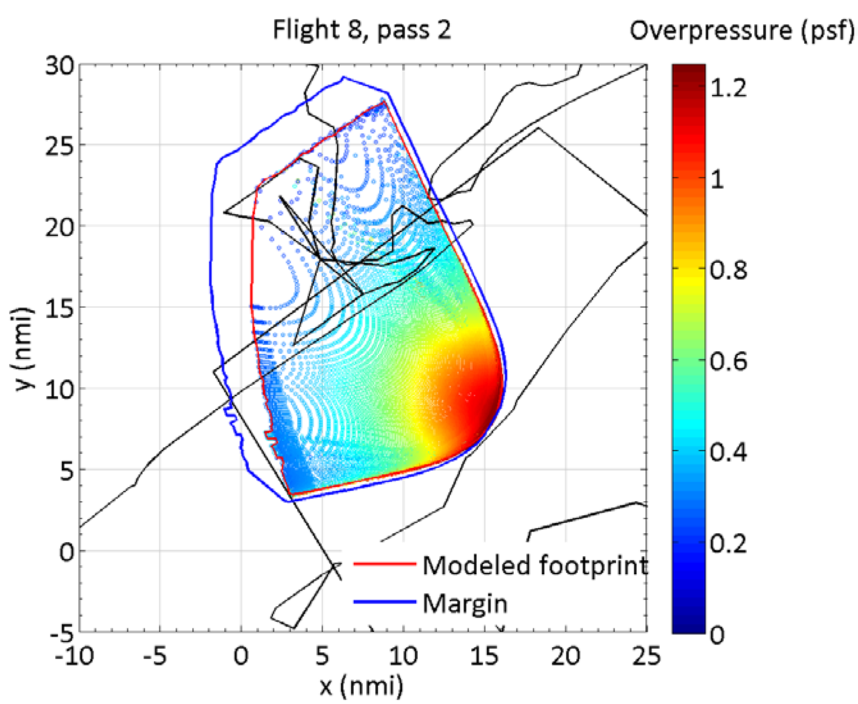


Figure 3. Example of modeled footprint edge (red inner shape) and its margins (blue outer shape)

For the purpose of determining metrics at subject locations, all survey participant locations within the recruitment area or near a monitor were included. Whether participant locations were within the footprint and also within its margins was tracked in the noise database using Boolean values to facilitate additional analyses.

The complete set of participant locations included several points in Houston, the Dallas area, and some as far away as Ecuador. Those points were not included in determination of metrics. Rather, the recruitment area (comprising four quadrilaterals A-D) was used as a criterion for deciding if metrics should be determined at a specific location (Figure 4). The recruitment area had four monitor locations near its borders: BRAVO at the southwestern edge on Galveston Island, and HOTEL, INDIA, and JULIET along the northwestern edge in Hitchcock, La Marque, and Texas City respectively. To include participant locations that were outside the recruitment area but relatively close to one of these four monitor locations, metrics were also determined at participant locations within 2 nmi of these four monitors regardless of whether the locations were inside the recruitment area. That dimension was selected to include clusters of participants outside the northwest border of the recruitment area without exceeding typical monitor location separation distances.

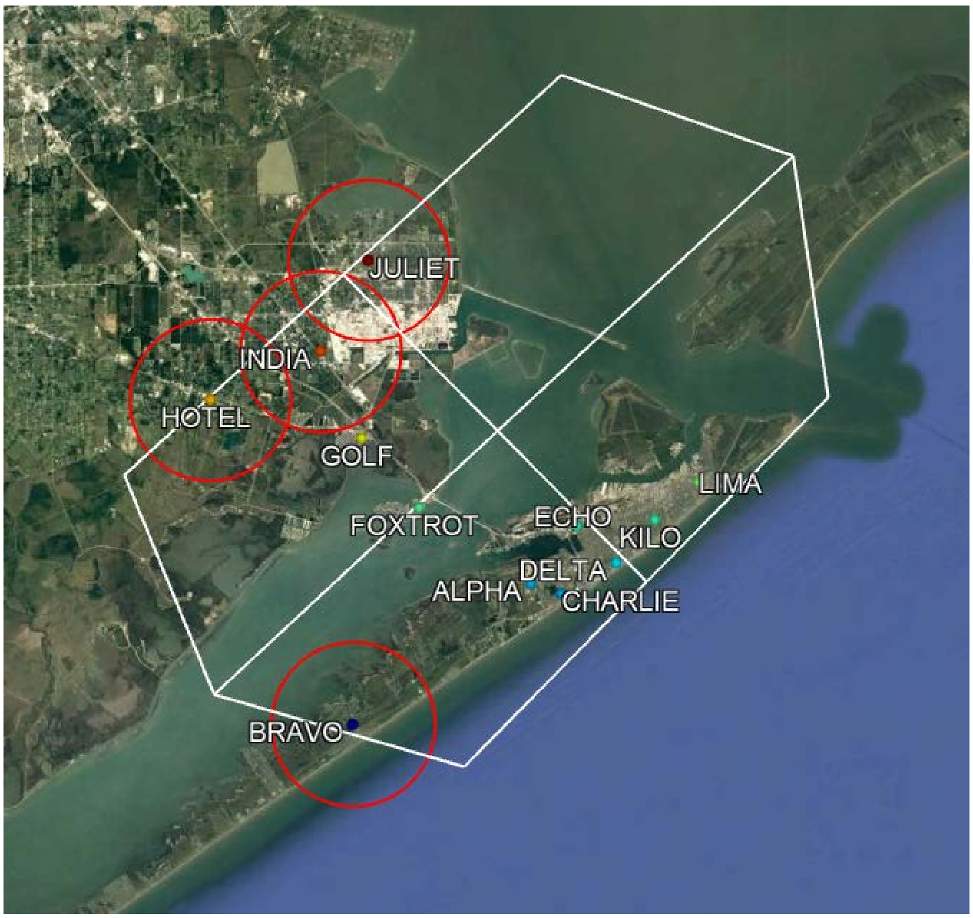


Figure 4. Recruitment area (white quadrilaterals) and monitor margins (red circles with radius 2 nmi) for monitors near borders.

Burgers equation modeling with PCBurg

To account for molecular vibrational relaxation effects on loudness metrics in propagation due to the molar concentration of water in the atmosphere the PCBoom Burgers equation module PCBurg 4 was used to supplement FOBoom/PCBFoot footprint modeling. PCBurg 4 is a much more computationally intensive tool than FOBoom 6.70, requiring up to several minutes to model propagation for a single ray[3]. As such, relatively coarse meshes comprising a few hundred points per footprint were constructed. An outline of this process is as follows:

1. Run FOBoom with keyword BURGERS to generate the necessary inputs to PCBurg (.age and .ssg files)
2. Run PCBFoot with run option 7 to add a full summary to the ASCII output file (.asc file)
3. Use WCON to identify the points that enclose the low peak overpressure portion of the footprint (generally where undertrack overpressure is less than around 0.5 psf), plus a few nmi offshore.
4. Construct a square grid of points with 1 nmi spacing, and remove all points not in the region specified in the previous step.
5. Using PCBFoot .asc files to generate a list of rays with containing PCBoom-referenced (x, y) coordinates of ground intersection points, (T_{ac}, ϕ) for each ray, and the PCBoom-identifier boom type (1 is carpet boom). The Matlab function load_PCBFoot_asc (included as an appendix) parses these values from .asc files.
6. For each square grid point, find the closest ray intersection point which has PCBoom identifier boom type 1; add the (x, y) ground intersection coordinates to the list of Burgers mesh points and add a line to the PCBurg batch file for the corresponding T_{ac}, ϕ.
7. Run PCBurg for each grid point identified in step 6 to calculate ground metrics with molecular relaxation effects. In practice, these runs were distributed across many machines and run concurrently in batch mode, at a sampling frequency of 51,200 Hz.
8. The output of PCBurg is a signature file for each grid point. Ground metrics are included in the header information for the second signature (indicated by header phrase "Refl = 1.9"). Parse ground metrics from all signature files and correlate with (x, y) locations from step 6.

[3] See "Recent Enhancements to NASA's PCBoom Sonic Boom Propagation Code", https://doi.org/10.2514/6.2019-3386, for a description of a faster implementation of Burgers equation propagation modeling, compared with PCBurg 4.

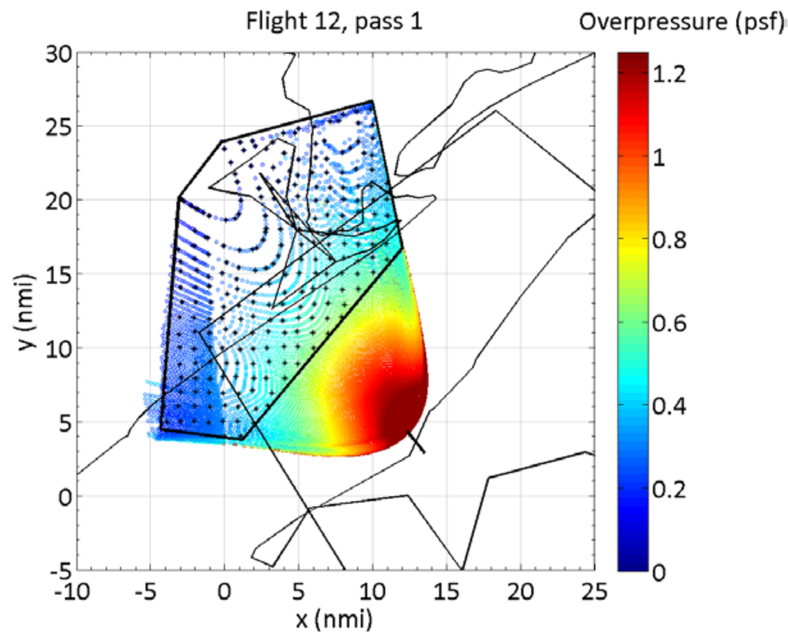


*Figure 5. Example Burgers mesh (black * points) overlaid on footprint from WCON (colored circles)*

Note that PCBurg only provides metrics for Pmax, PL, ASEL, CSEL and unweighted SEL. Time domain pressure signatures (in psf) are included in the data archive so a further analysis could include calculation of other metrics from PCBurg output files. Signature files in that archive have names such as “SIG_F12P1_195.TXT” indicating the flight number, pass number, and mesh point number.

Location types for metric determination

Prior to analysis, latitude and Longitude coordinates describing survey participant locations and monitor locations were converted to a local coordinate system using the Haversine formula. Based on a combination of participant location relative to footprint and recruitment area, usable monitor metrics available, proximity to monitors, and some interrelationships among these quantities, each combination of event/metric/location was assigned a “noise method type” that describes how metrics were determined in each instance. These noise method types are tabulated below and the corresponding methods are described in the following text. These types can be grouped into three categories:

1. Noise method types 1, 2, and 3 are normal scenarios in which the interpolation method depends on proximity to monitors and footprint margins, and whether PCBurg metrics were available.
2. Noise method types 0, 4, and 5 indicate scenarios where no metric determination could be made due to missing data or locations outside study area, and levels were set to zero,
3. Noise method types 6, 7, 8, and 9 are special cases dealing with locations that were both outside the Burgers-mesh modeled footprint and in locations downtrack of the Bayou Vista area monitor (GOLF) when the GOLF monitor level was missing and/or when monitor levels at further downtrack locations HOTEL, INDIA, or JULIET were missing.

Noise method type	Location description	Metric level at participant location
0	No participant location data	0
1	Within 0.5 nmi of usable monitor	Monitor level
2	Inside the Burgers-mesh modeled footprint	Burger mesh interpolation anchored to measured levels
3	Inside study area and either outside Burgers-mesh modeled footprint or Burgers metrics unavailable	Interpolation/extrapolation of measured metrics
4	Outside study area	0
5	All monitor levels below ambient threshold	0
6	More than 2 nmi downtrack from GOLF, outside Burgers-mesh modeled footprint, with 1–2 monitors missing from set of HOTEL, INDIA, JULIET	Interpolation/extrapolation across HOTEL, INDIA, JULIET monitor(s) only
7	Downtrack from GOLF, outside Burgers-mesh modeled footprint, with all monitors missing from set of HOTEL, INDIA, JULIET	Using level from Bayou Vista (GOLF)
8	Less than 4 nmi downtrack of Tiki Island (FOXTROT), outside Burgers-mesh modeled footprint, with all monitors missing from set of GOLF, HOTEL, INDIA, JULIET	Using level from Tiki Island (FOXTROT)
9	More than 4 nmi downtrack of Tiki Island (FOXTROT), outside Burgers-mesh modeled footprint, with all monitors missing from set of GOLF, HOTEL, INDIA, JULIET	Using level from Tiki Island (FOXTROT)

Noise method type 0: the participant location could not be determined; metrics levels were set to zero.

Noise method type 1: Participant location was less than 0.5 nmi from a monitor with a usable level. Metric level was set to the nearest monitor level. By comparing estimated uncertainty of the inverse distance weighted interpolation with downtrack and lateral trends in modeled PL, this distance was selected as a balance between the two.

Noise method type 2: Participant location was inside the Burgers-mesh modeled footprint, metric type was part of the Burgers mesh dataset, and there was at least one usable monitor level in the modeled footprint. For this method, the Burgers mesh was anchored to monitor levels and relative level offsets between the monitor location and participant location were determined from the Burgers mesh. This was accomplished in Matlab 2012a as follows. First, 2D linear interpolation was used to determine the Burgers mesh level at the *i*th monitor location.

```
burg_at_mon(i,1) = griddata(burgers_mesh_xy(:,1), burgers_mesh_xy(:,2),
burgers_metric_mesh, monitor_xy_usable(i,1), monitor_xy_usable(i,2),
'linear');
```

Similarly, the Burgers mesh level at the participant location was also determined:

```
burg_at_ploc(sub_idx) = griddata(burgers_mesh_xy(:,1), burgers_mesh_xy(:,2),
burgers_metric_mesh, part_locations(sub_idx,1), part_locations(sub_idx,2),
'linear');
```

The metric at a participant location was then estimated using the Burgers mesh offset from the monitor level in the previous step:

```
metric_at_ploc(i) = boom_measurements_usable(i) - burg_at_mon(i) +
burg_at_ploc(sub_idx);
```

This gives an estimate of the metric level at a participant location based on anchoring the Burgers mesh to a single monitor level. For each participant location this process was repeated for all usable monitor levels such that a set of metric estimates at one location was produced. These metric levels were then averaged using the inverse-distance weighted averaging scheme described below in “Noise method type 3”. That scheme applies larger weights to metric estimates based on levels from monitors closer to the participant location. The result was a single metric level at a participant location including contributions from Burgers equation modeling and all usable measured levels for that event.

Noise method type 3: Participant location was outside the Burgers-mesh modeled footprint or metric type was not part of Burgers mesh dataset. Burgers-mesh-guided interpolation was not available, so an inverse distance weighted averaging scheme based solely on measured metrics was used. This is similar to the method described in the WSPR 2011 final report. For a set of N measured metrics with levels u_i at locations x_i, the metric level at a location was determined as follows:

$$u(x) = \sum_{i=1}^{N} \frac{w_i(x)u_i}{\sum_{j=1}^{N} w_j(x)}$$

In this expression, weights w_i were determined for each measured metric based on the distance d between the measurement location x_i and the location of interest x:

$$w_i = \frac{1}{d(x, x_i)^p}$$

In this application, a power parameter value $p = 3$ was used based on trials in which a measured level was dropped from the dataset and interpolation was used to estimate the level at that location. Higher p values increase the influence of levels near the interpolated point whereas lower p values give greater weight to levels father away. Over a range of $p = 0.5$ to 5, variation in interpolated PL due to varying p was typically 2–4 dB.

Noise method type 4: Participant location was outside the recruitment area and more than 2 nmi from a monitor with a usable level. Metric levels were set to zero.

Noise method type 5: All monitor levels were below the ambient threshold (1 dB, 3 dB, or 5 dB above ambient). Since all the interpolation/extrapolation schemes used in this analysis require at least one measured level, metric levels were set to zero.

Noise method type 6: Participant location was outside the Burgers-mesh modeled footprint, more than 2 nmi downtrack from GOLF (Bayou Vista), and 1 or 2 of the Hitchcock / La Marque / Texas City area monitors (HOTEL, INDIA, JULIET) did not have a usable signal. Inverse distance weighted averaging was used (as with noise method type 3) except that only usable levels from Hitchcock / La Marque / Texas City area monitors were included. This was done to eliminate influence from uptrack monitors in the averaging process.

Noise method type 7: Participant location was outside the Burgers-mesh modeled footprint, downtrack from GOLF (Bayou Vista), and none of the Hitchcock / La Marque / Texas City area monitors (HOTEL, INDIA, JULIET) had a usable signal. In this case, level was set to the monitor level from the next closest monitor: GOLF in Bayou Vista.

Noise method type 8: Participant location was outside the Burgers-mesh modeled footprint, in Bayou Vista / Tiki Island area, and none of the Bayou Vista (GOLF) or the Hitchcock / La Marque / Texas City monitors (HOTEL, INDIA, JULIET) had a usable signal. Participant location was downtrack of FOXTROT monitor, but not more than 4 nmi away. In this case, level was set to the monitor level from the next closest monitor: FOXTROT on Tiki Island.

Noise method type 9: Participant location was outside the Burgers-mesh modeled footprint, more than 4 nmi from Tiki Island, and none of the Bayou Vista (GOLF) or the Hitchcock / La Marque / Texas City area monitors (HOTEL, INDIA, JULIET) had a usable signal. In this case, level was set to the monitor level from the next closest monitor: FOXTROT on Tiki Island. This is the same method used as in noise method type 8, except that the participant location was more than 4 nmi from FOXTROT and possibly up to 8 nmi away. This case was separated into a different noise method type due to the larger distances (and thus higher uncertainty) associated with these locations.

The participant noise databases (QSF18_Metrics_subject_locs_0650msWindow_01dB_above_amb_v3, for example) include participant location assignment codes, noise method types for each metric, and Boolean values indicating if a specific location is inside the modeled footprint, inside footprint margins, and inside the study area. Using these fields, cumulative noise doses can be calculated using more or less restrictive requirements.

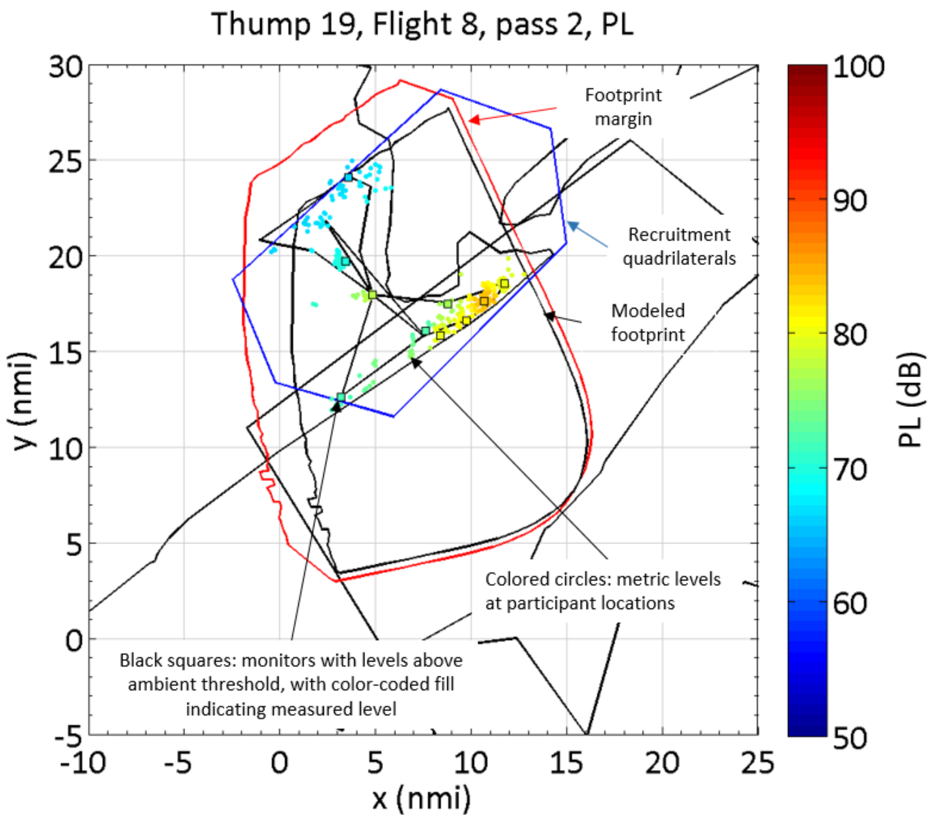


Figure 6. Example of metrics at participant locations

Supplemental MATLAB 2012a Code

```
function [footprint, n_phi, AC_time] = load_PCBFOOT_asc(filename)
% [footprint, n_phi, AC_time] = load_PCBFOOT_asc(filename)
% This function read the full .asc output from PCBFoot v 6.66
% add run option 2 for full summary output in .asc file
%
% footprint columns:
% 1 x (ft)
% 2 y (ft)
% 3 Tac (sec)
% 4 phi (deg)
% 5 Pmax (psf)
% 6 Boom type
% From PCBFOOT.FOR
% *          ITYP       Type of boom. 0 = none, 1 = carpet boom,         *
% *                     2 = maximum focus boom, 3 = post-focus boom      *
% *                     -1 = missing signature.                          *
% footprint output stacks n_phi rows for each isopemp
%
% n_phi gives the number of points in each isopemp
% AC_time is the aircraft time associated with each isopemp
```

```
[FID, MSG] = fopen(filename, 'r');
fprintf(1, 'Reading %s\n', filename);

n_pnts_t = 0;
footprint = [];
n_phi = [];
AC_time = [];

hline = fgets(FID);
while ~feof(FID)
    if ~isempty(strfind(hline, 'Time'))
        n_pnts_t = n_pnts_t + 1;

        output = sscanf(hline, '%s %s %s %f');
        AC_time(n_pnts_t) = output(end);

        % read subheader line
        hline = fgets(FID);

        n_phi(n_pnts_t,1) =  0;
        while size(hline,2)>3
            output = sscanf(hline, '%f %f %f %f %f %i');
            if ~isempty(output)
                % Only save points if boom type is not “none”
                if output(5)>0
                    n_phi(n_pnts_t,1) = n_phi(n_pnts_t,1) + 1;
                    footprint = [footprint; [output(2), output(3),
AC_time(n_pnts_t), output(1), output(5), output(6)]];
                end
            end
            hline = fgets(FID);
        end
    end
    hline = fgets(FID);
end
fclose(FID);

end
```

P. Daily Noise Dose Calculation

The following pages provide Appendix P. This appendix file is provided separately from the main body of the report.

Memorandum

U.S. Department

of Transportation

Subject:	QSF-18: Calculation of Daily Noise Dose	Date:	25 March 2019
From:	Robert Downs and Juliet Page, Volpe V-324	Revised:	26 July 2019
To:	Jonathan Rathsam, NASA and Robert Hunte, APS		*Project: VPH9*

QSF-18: Calculation of Daily Noise Dose

Daily noise doses are calculated for each participant ID for nine flight days using metrics at participant locations. Single event metric levels are tabulated in spreadsheets with file names of the form:

`QSF18_Metrics_subject_locs_XXXXmsWindow_YYdB_above_amb_v3.xlsx`

where XXXX is either 0650 or 3000 (representing the window length in milliseconds used to compute metrics), and YY is 01, 03, or 05 (representing the level above ambient criterion to determine which measured metrics are used in the analysis).

As part of determining metrics at participant locations, each location is classified as inside or outside the modeled footprint and its margins. Footprint margins were estimated in an earlier analysis as 0.5 nmi in the lateral direction and 2.9 nmi in the downtrack direction. Booms 48 – 52 are characterized by higher overpressures at cutoff, and are treated differently in the margin analysis. For that set of booms, which occurred on flight day 9, downtrack margins are 4.2 nmi.

For each of the six sets of metrics described above, daily noise doses are calculated using all participant locations inside the footprint margins. Noise dose for a given flight day is specified by cumulative metrics calculated in a manner similar to Day Night Level (DNL) or Community Noise Equivalent Level (CNEL). Since no booms occurred outside the local time period 0700 – 1900, no penalties were added for evening or night hours. Cumulative levels in dB are calculated for each combination of participant ID, flight day, and *N* single event noise metrics (SE) as:

$$\text{Cumulative level} = 10\log_{10}\left[\sum_{i=1}^{N} 10^{SE_i/10}\right] - 49.4$$

The cumulative level is essentially an energy sum of single event levels, with a standard factor of 49.4 dB removed to account for normalization to a 24 hour day[1]. For example, for one flight day a participant experiencing the five single event PLs tabulated below would receive a noise dose of 38.1 dB.

PLdB	10^(0.1*PL,i)
79.7	93325430.1
83.3	213796209.0
82.9	194984460.0
74	25118864.3
75.9	38904514.5
	sum(10^(0.1*PL,i)) = 566129477.8
	PLDN (dB) = 38.1

Noise exposure metrics at locations outside the footprint and margin were extrapolated to estimate single event noise exposure levels using measured metrics with both 650 ms and 3000 ms windows. In each set of metrics, locations outside the footprint and outside the margin were marked with Boolean values to enable further analyses. Metrics values at locations outside footprint margins were excluded from the summation of single event noise exposures to determine daily noise exposure levels. Of 13213 single event metrics, 4435 extrapolated values were excluded because signals outside the footprint and margin tended to be more rumbly and less impulsive than signals within the footprint and margin, along with 89 values at La Marque area locations for cases when all recorded signals from La Marque and nearby Bayou Vista monitors were not sufficiently above the ambient level. The decision could be viewed as inconsistent since the extrapolated single events were retained for single event dose-response analysis, but excluded for cumulative dose-response analysis. In general, neither single event nor cumulative dose-response analysis results are likely to change dramatically regardless of how doses are calculated, as there were simply so few highly annoyed responses. The exclusion of 4524 extrapolated single event noise exposure values correspond to 10 (of the total 17) highly annoyed daily summary survey responses and 1914 (of the total 2041) not highly annoyed daily summary survey responses. Reanalysis of the data using different dose measurement algorithms is a possibility for future research.

The following tables provide sample daily noise exposure calculations, in which values in grey cells are not used because participant was not within the footprint or its margins.

BOOM_ID	BOOM_NUMBER	PARTICIPANT_ID	in_margin	PL	10^(0.1*PL)
F01P1	1	100258	0	0	1
F01P2	2	100258	0	73.3	21379620.9
F01P3	3	100258	0	87.1	512861384
F02P1	4	100258	0	73.4	21877616.24
F02P2	5	100258	0	81.6	144543977.1
F03P1	6	100258	1	69	7943282.347
F03P2	7	100258	1	71.3	13489628.83
				PLDN	**23.9 dB**

[1] 10 $\log_{10}$(24 hours/day × 60 minutes/hour × 60 seconds/minute) ≈ 49.4. See, for example, "Calculation of Day-Night Levels Resulting from Civil Aircraft Operations", EPA Report 550/9-77-450, Bishop et al., March 1976.

BOOM_ID	BOOM_NUMBER	PARTICIPANT_ID	in_margin	PL	10^(0.1*PL)
F04P1	8	100258	0	70	10000000
F04P2	9	100258	1	67.7	5888436.554
F04P3	10	100258	1	67.2	5248074.602
F05P1	11	100258	0	67.9	6165950.019
F05P2	12	100258	0	71.7	14791083.88
F05P3	13	100258	0	74	25118864.32
				PLDN	**21.1 dB**

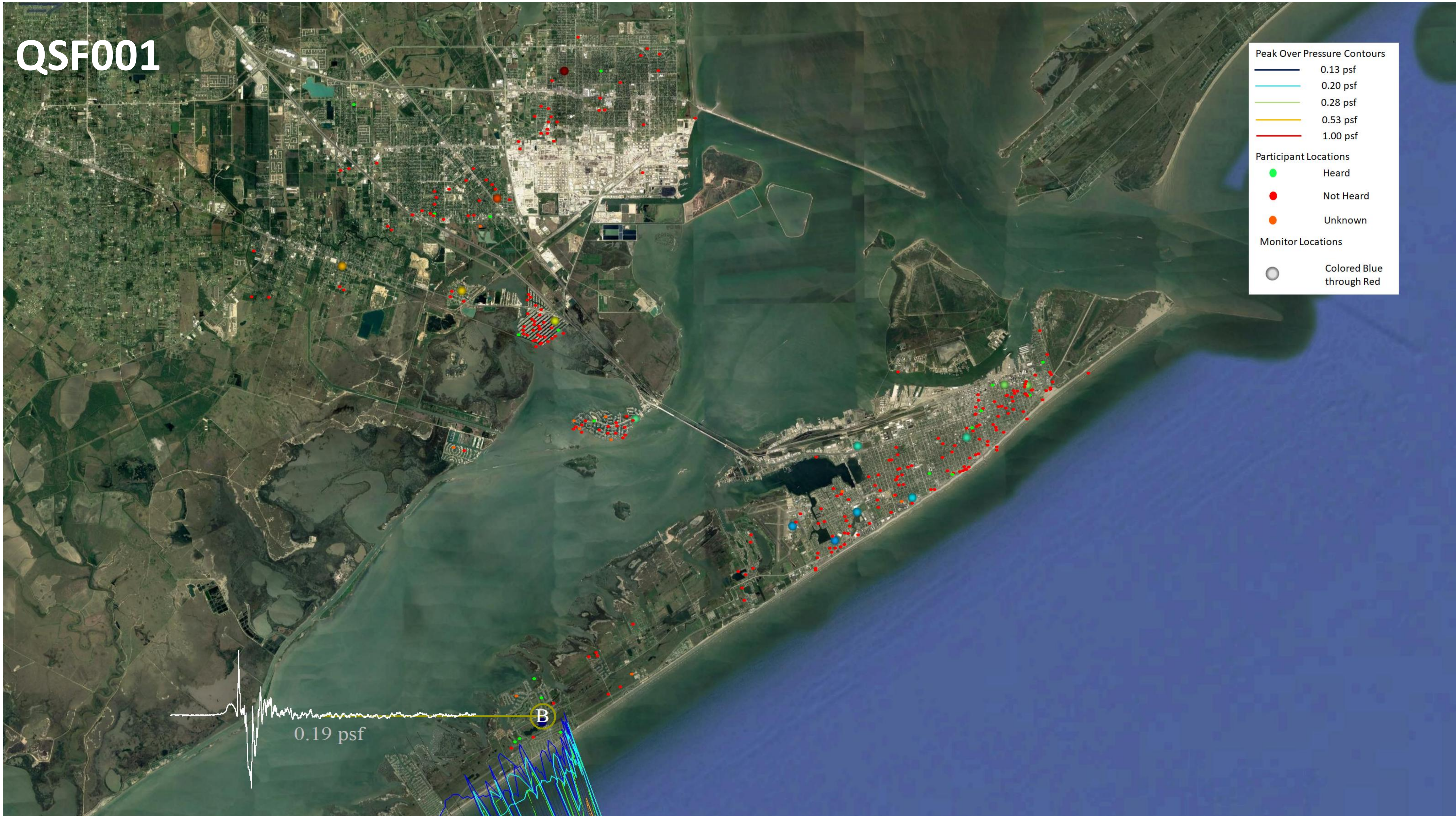
Q. QSF18 Measured Sonic Booms Across the Area

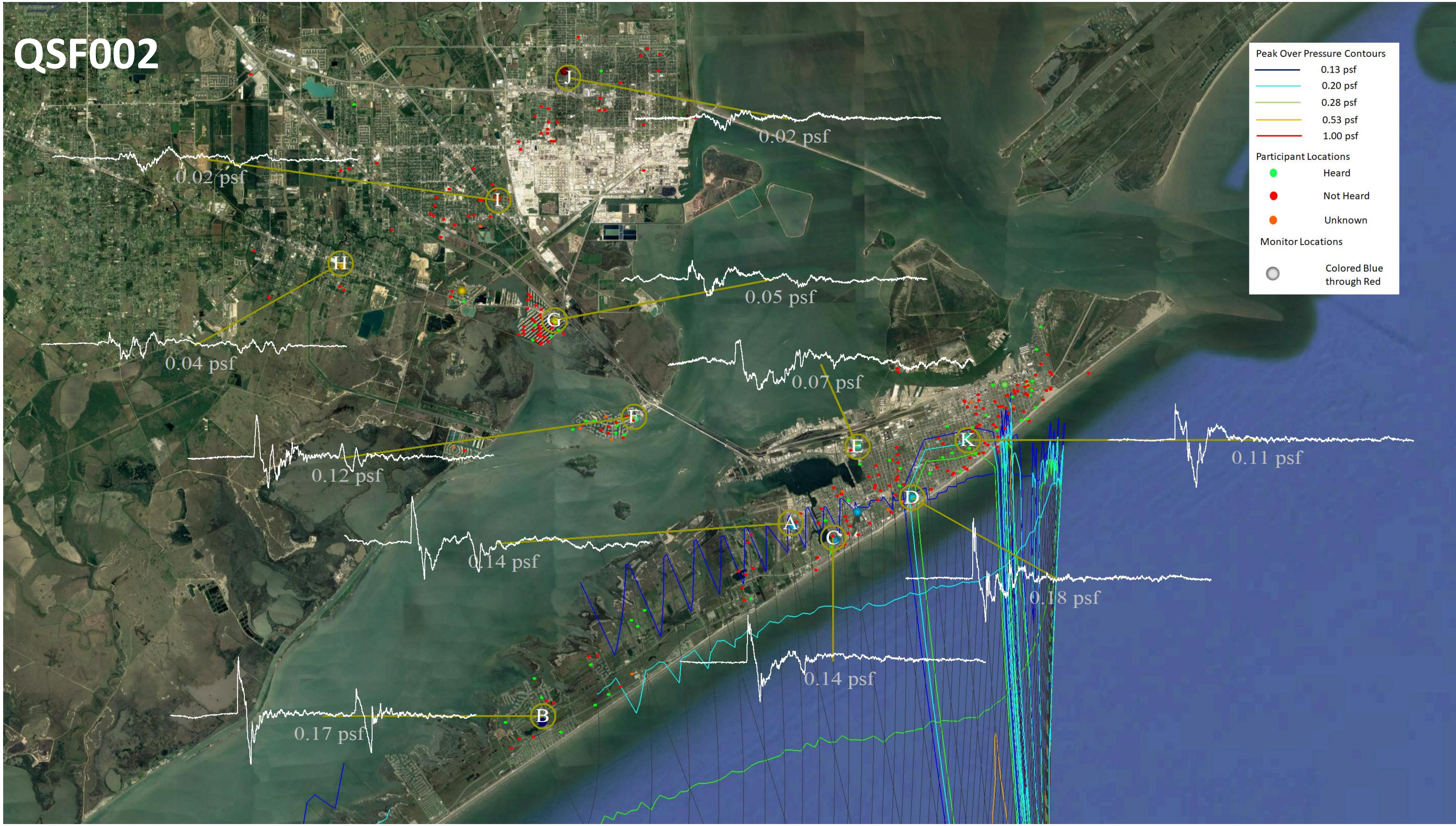
The following pages provide Appendix Q. This appendix file is provided separately from the main body of the report”.

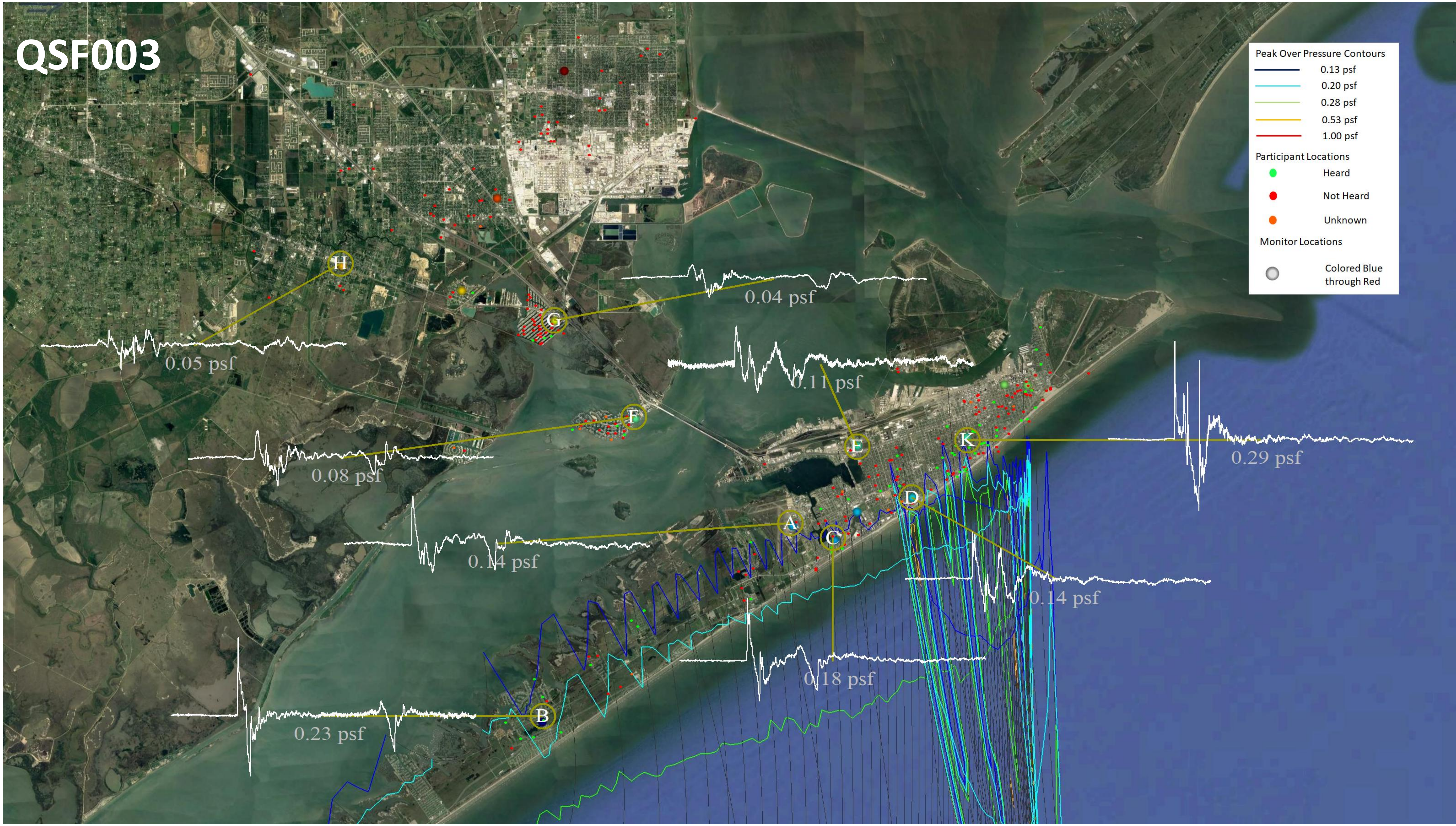
QSF-18 Measured Sonic Booms Across the Area

The following figures show the calculated footprint's peak overpressure contours overlaid on the study area with 3 seconds of recordings from monitors Alpha (A) through Lima (K) which were found to have recorded noise emitted from the aircraft during the supersonic portion of its trajectory. There are only four passes by the aircraft during which the Lima (L) recorder was working. The peak overpressure measured for each of those recordings is noted in psf on each graph. All time traces are graphed to the same scale.

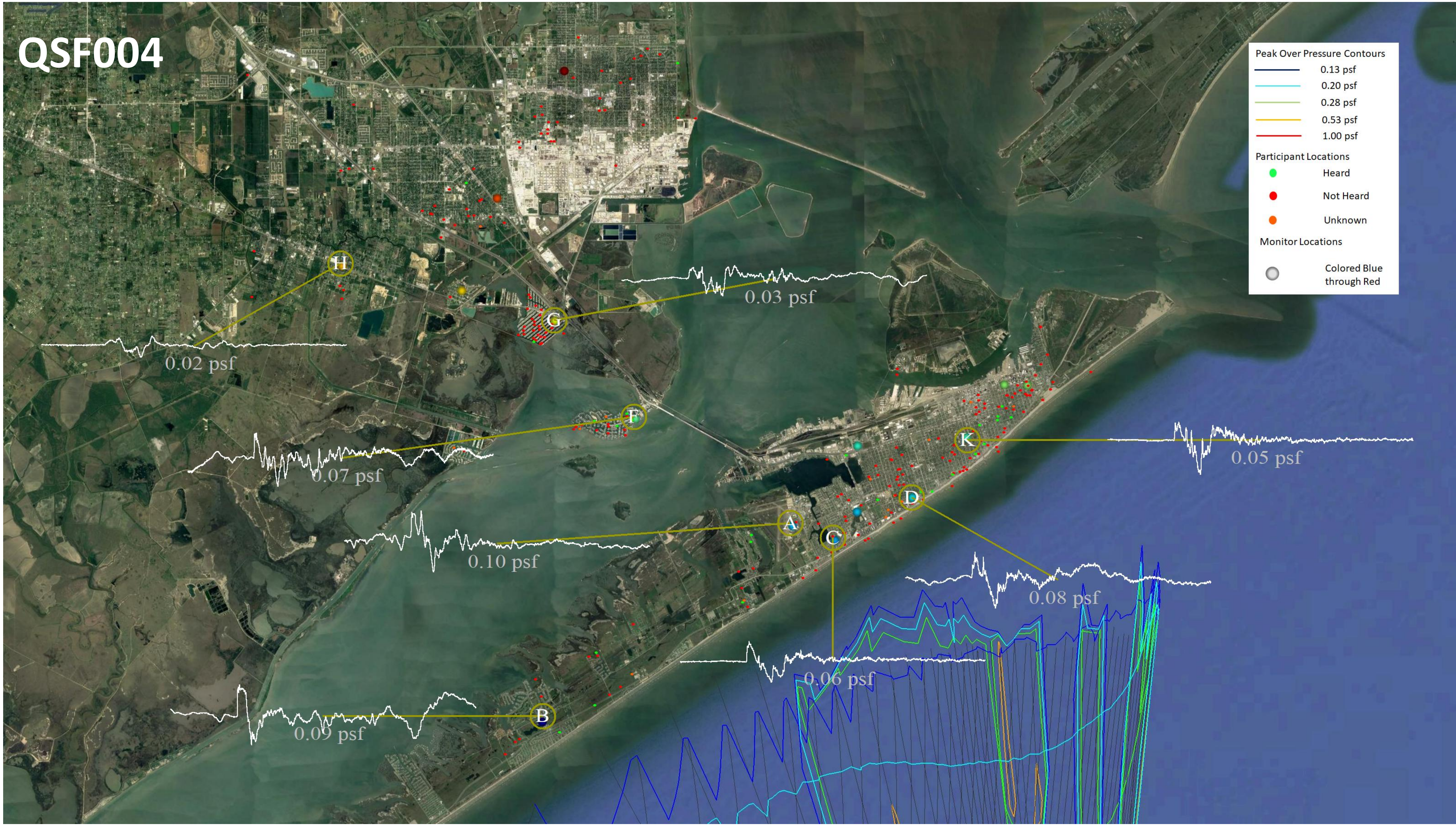
The participant locations and whether they heard an event is shown as small dots with the appropriate color. A green dot indicates a participant noted hearing that event on the single event survey. If they reported hearing no thumps on the daily summary, then the color is red. If they reported hearing a thump on the daily summary with their location estimated within the footprint and the time they heard the thump could not be established, then the color is orange.

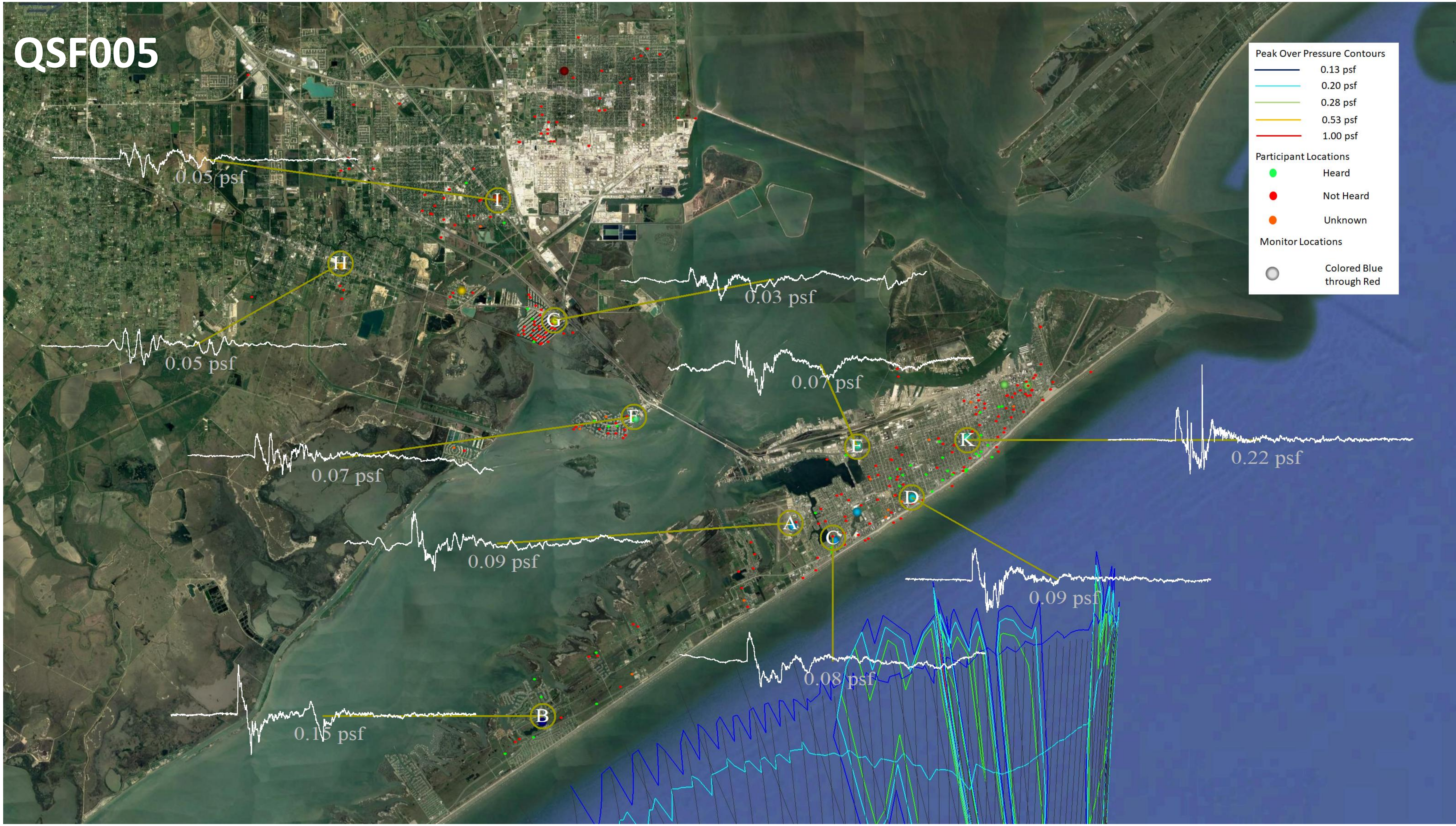

QSF001
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
B
0.19 psf


QSF002
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.02 psf
I
0.02 psf
H
0.04 psf
G
0.05 psf
0.07 psf
F
0.12 psf
E
K
0.11 psf
D
0.18 psf
A
0.14 psf
C
0.14 psf
B
0.17 psf

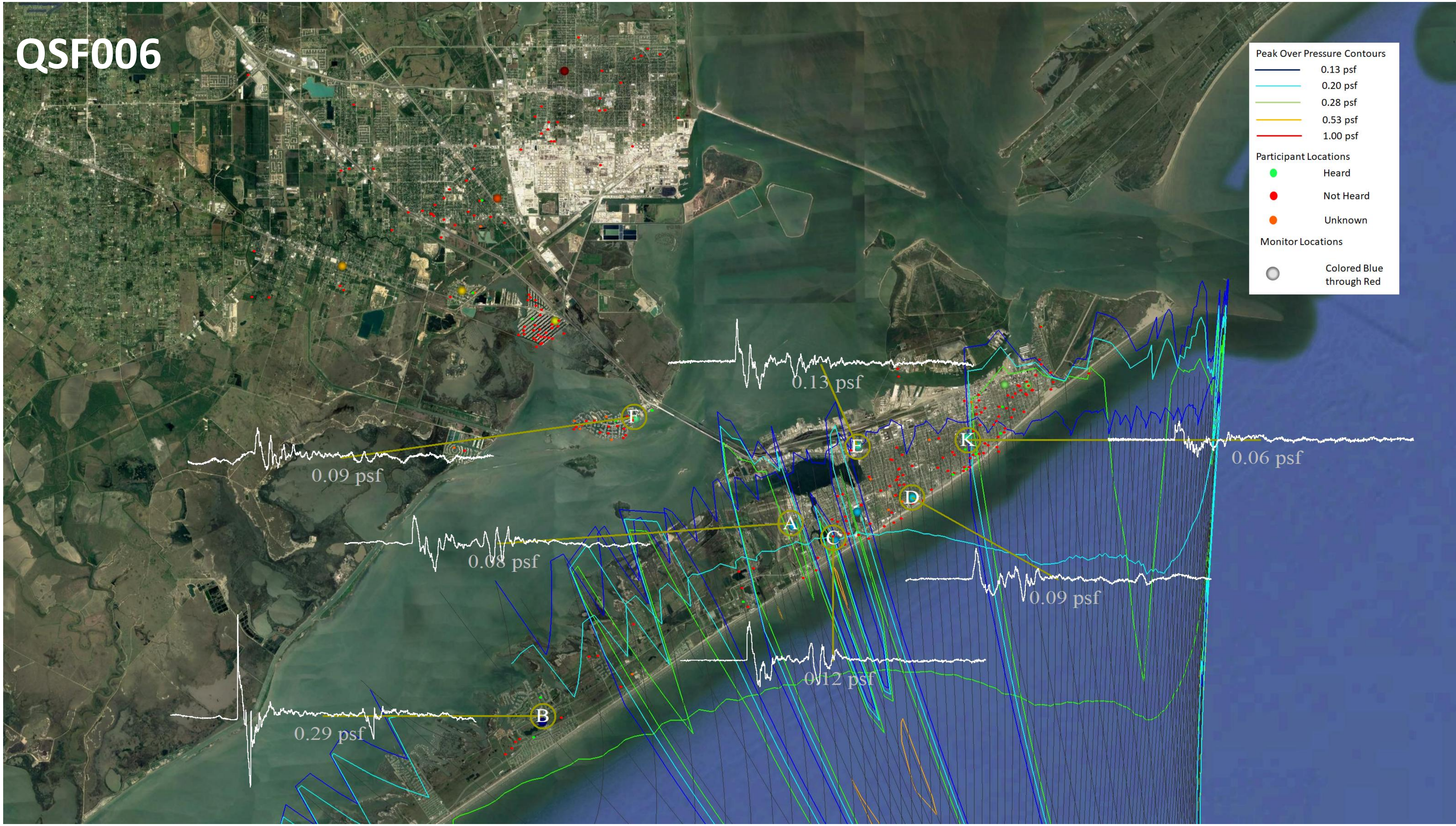


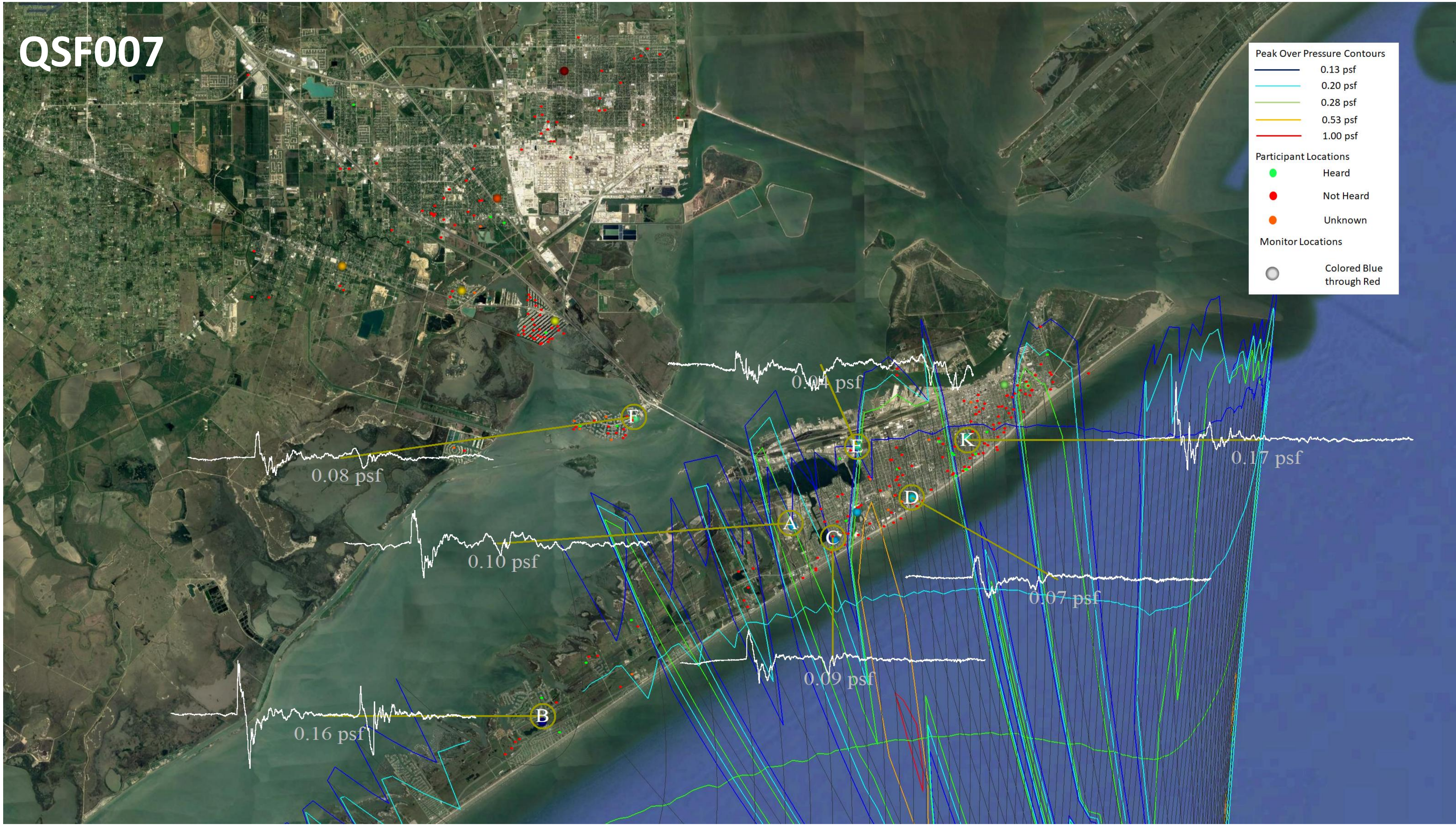
QSF003
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
H
G
F
E
K
D
A
C
B
0.04 psf
0.05 psf
0.11 psf
0.08 psf
0.29 psf
0.14 psf
0.14 psf
0.18 psf
0.23 psf

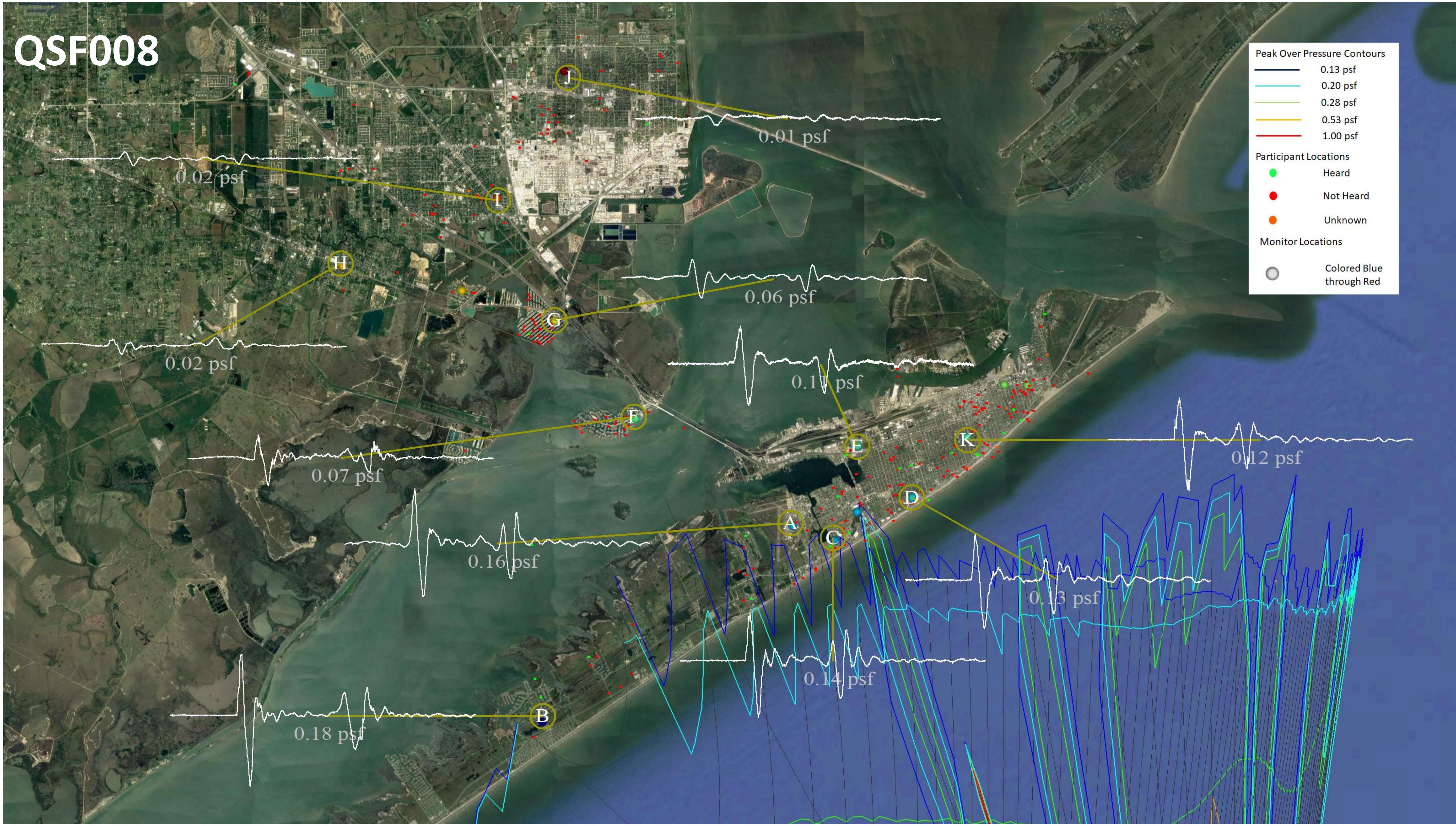

QSF004
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
H
0.02 psf
G
0.03 psf
F
0.07 psf
A
0.10 psf
C
0.06 psf
D
0.08 psf
K
0.05 psf
B
0.09 psf

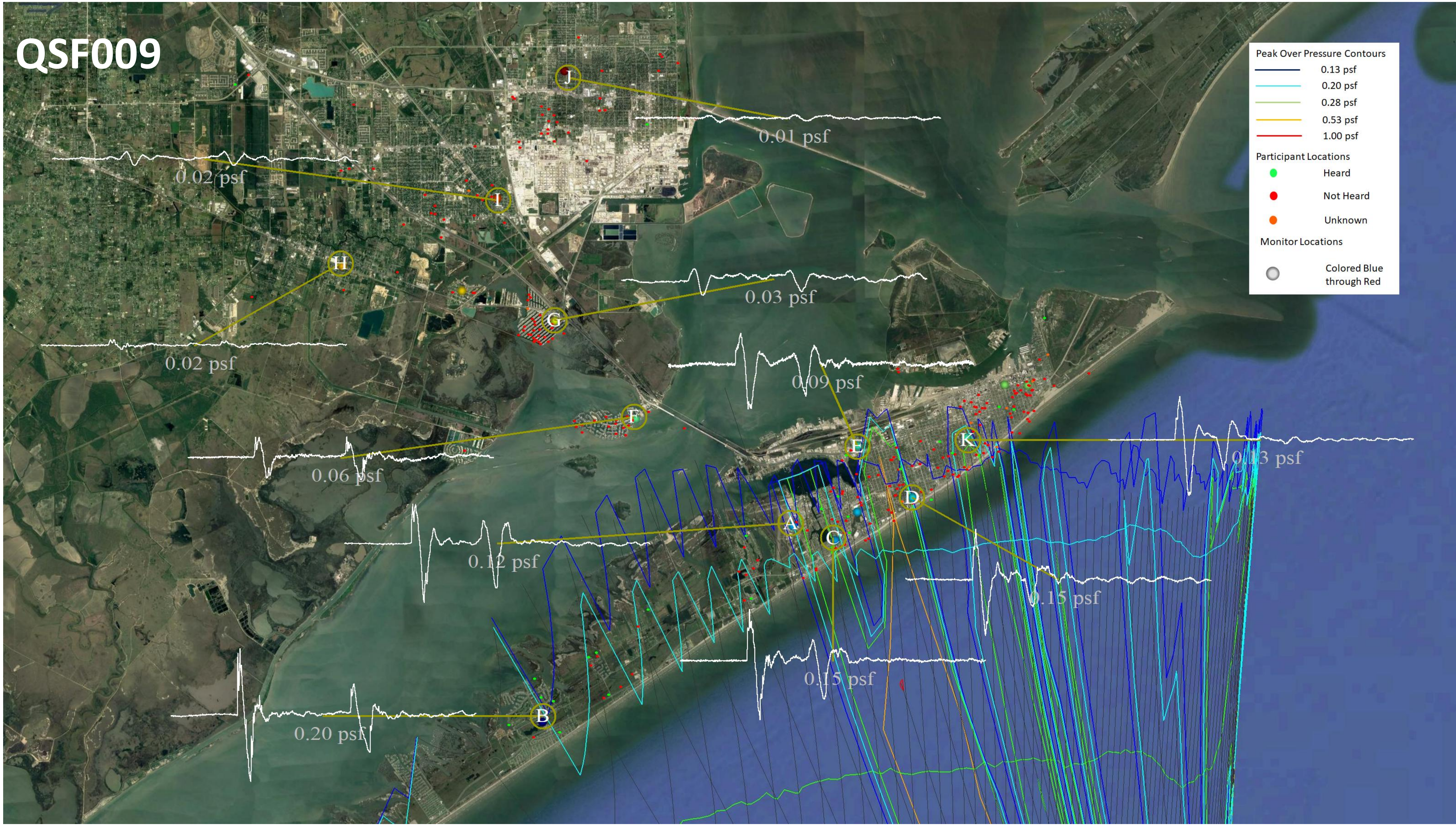


QSF005
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
0.05 psf
0.05 psf
0.03 psf
0.07 psf
0.07 psf
0.22 psf
0.09 psf
0.09 psf
0.08 psf
0.15 psf
A
B
C
D
E
F
G
H
I
K

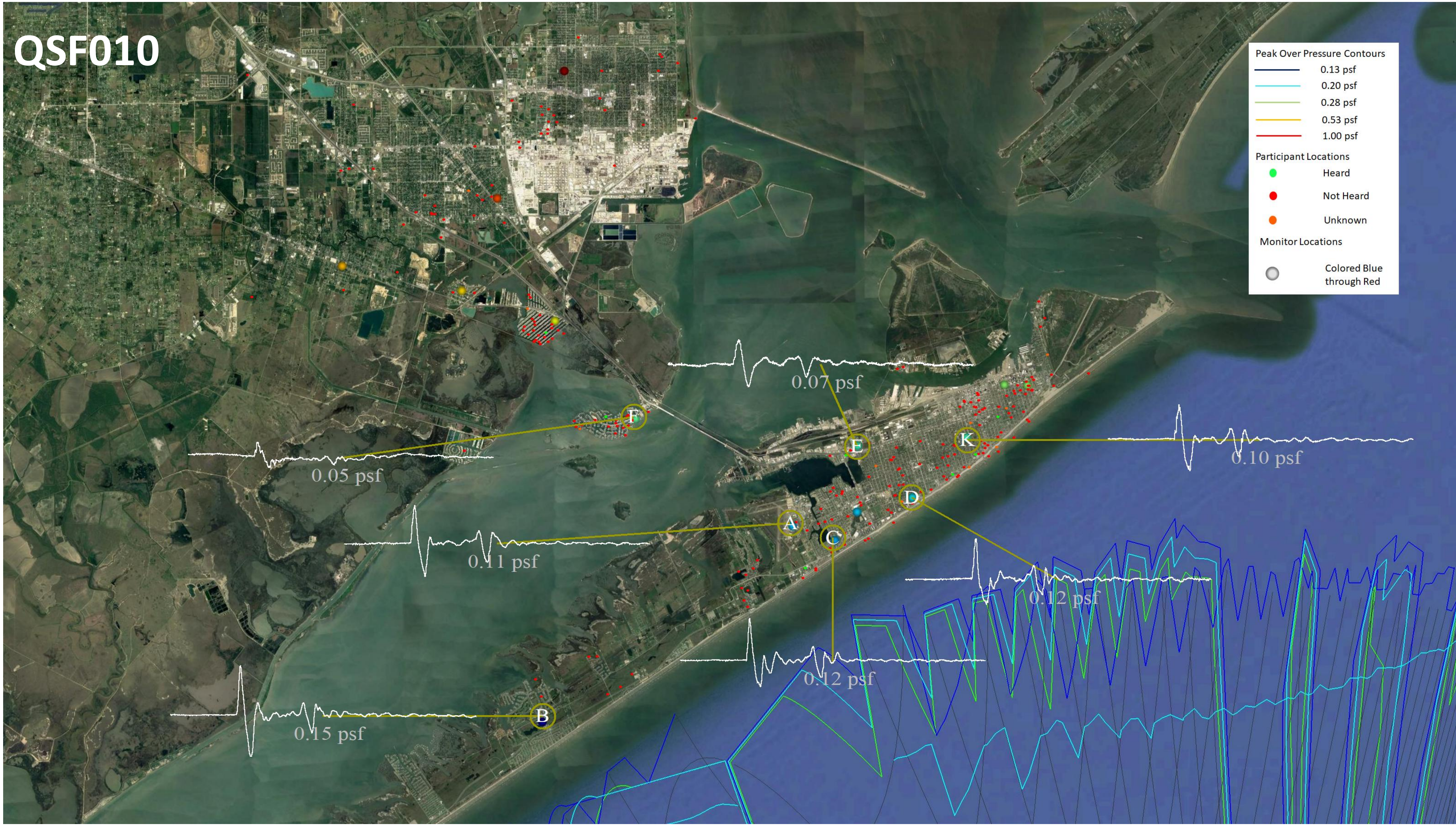

QSF006
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
F
0.09 psf
0.13 psf
E
K
0.06 psf
D
A
C
0.08 psf
0.09 psf
0.12 psf
B
0.29 psf


QSF007
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
F
0.08 psf
E
K
0.17 psf
D
A
C
0.10 psf
0.07 psf
0.09 psf
B
0.16 psf

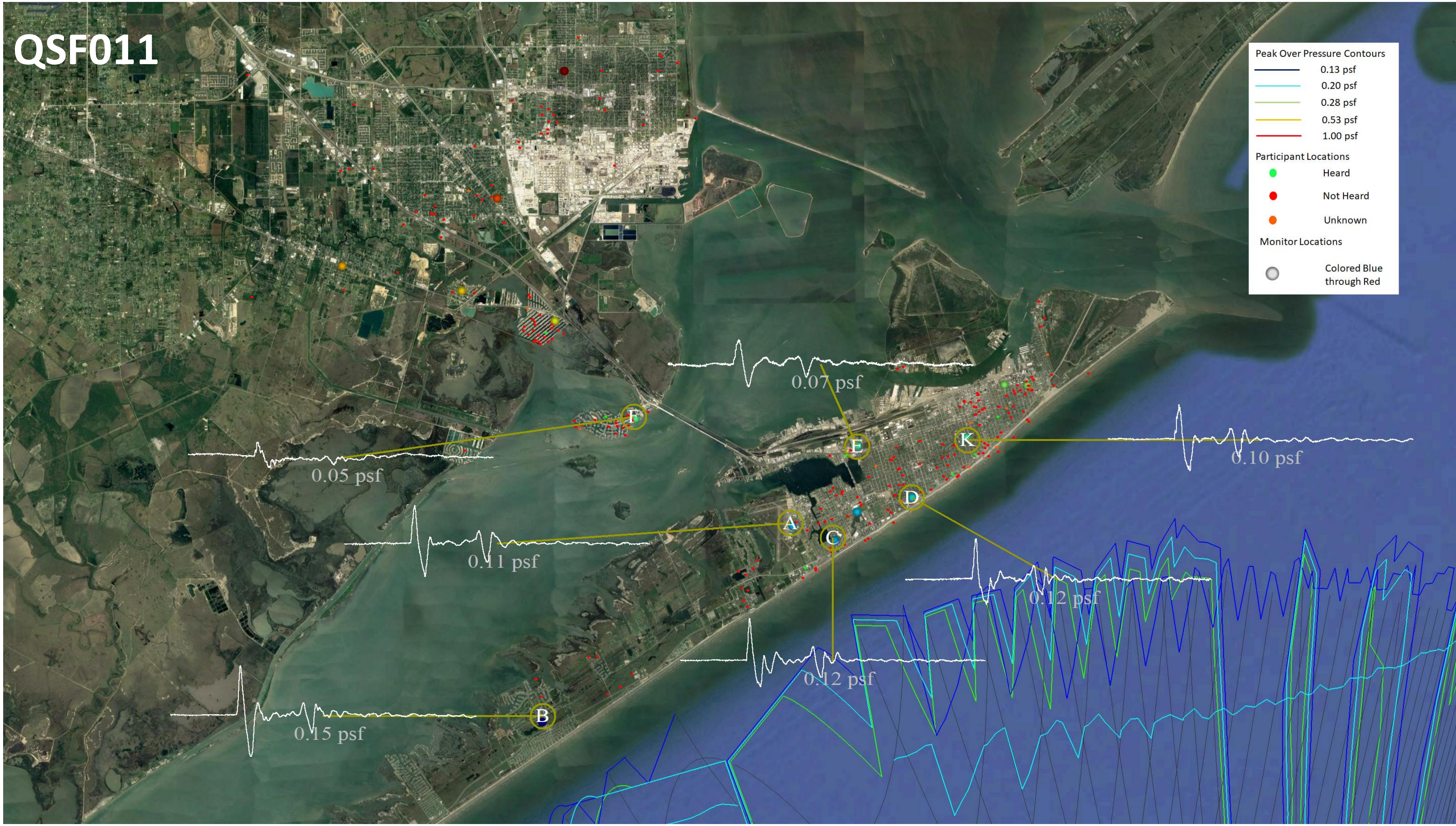

QSF008
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.01 psf
I
0.02 psf
H
0.02 psf
G
0.06 psf
0.11 psf
F
0.07 psf
E
K
0.12 psf
D
A
C
0.16 psf
0.13 psf
0.14 psf
B
0.18 psf

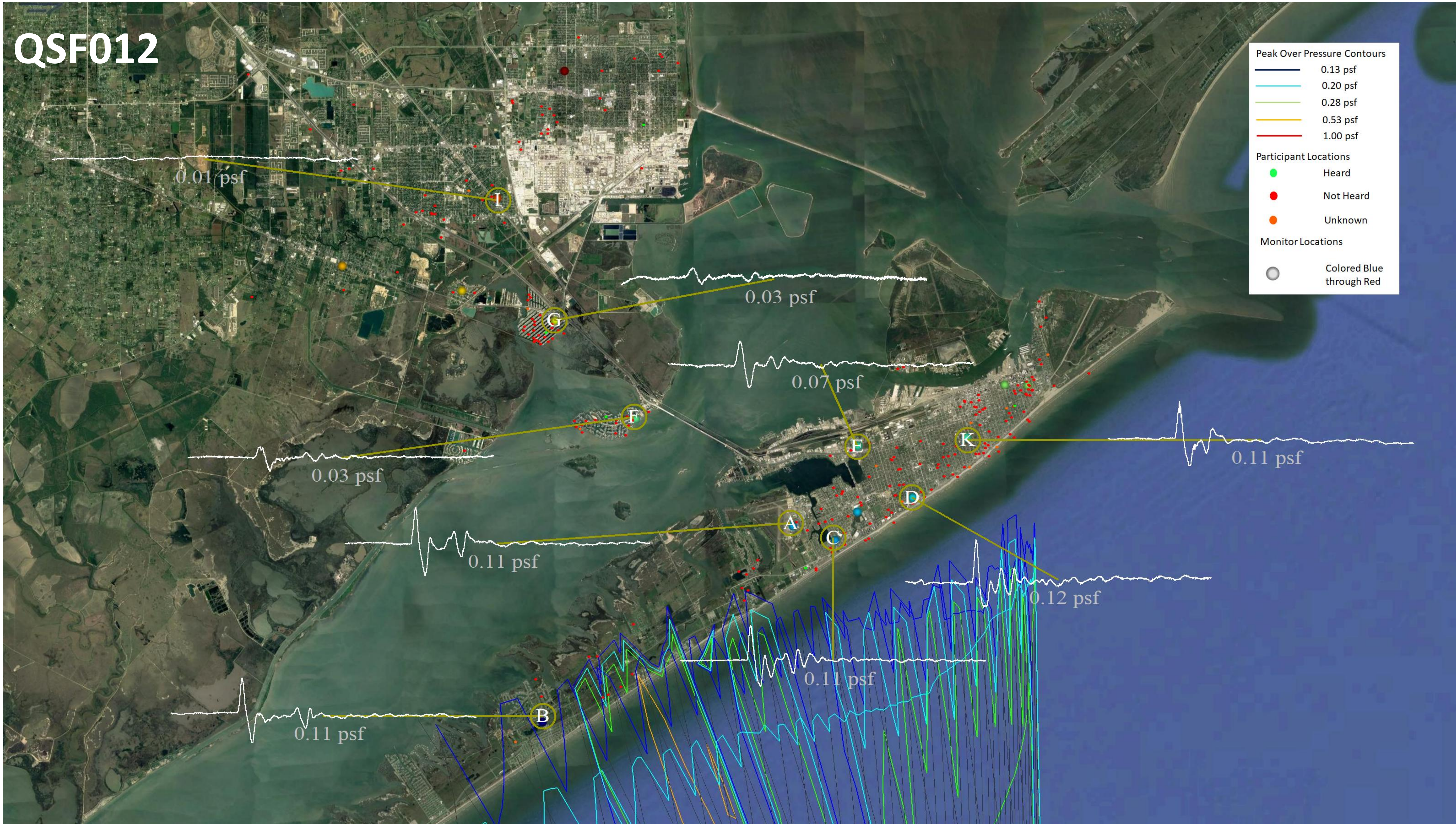


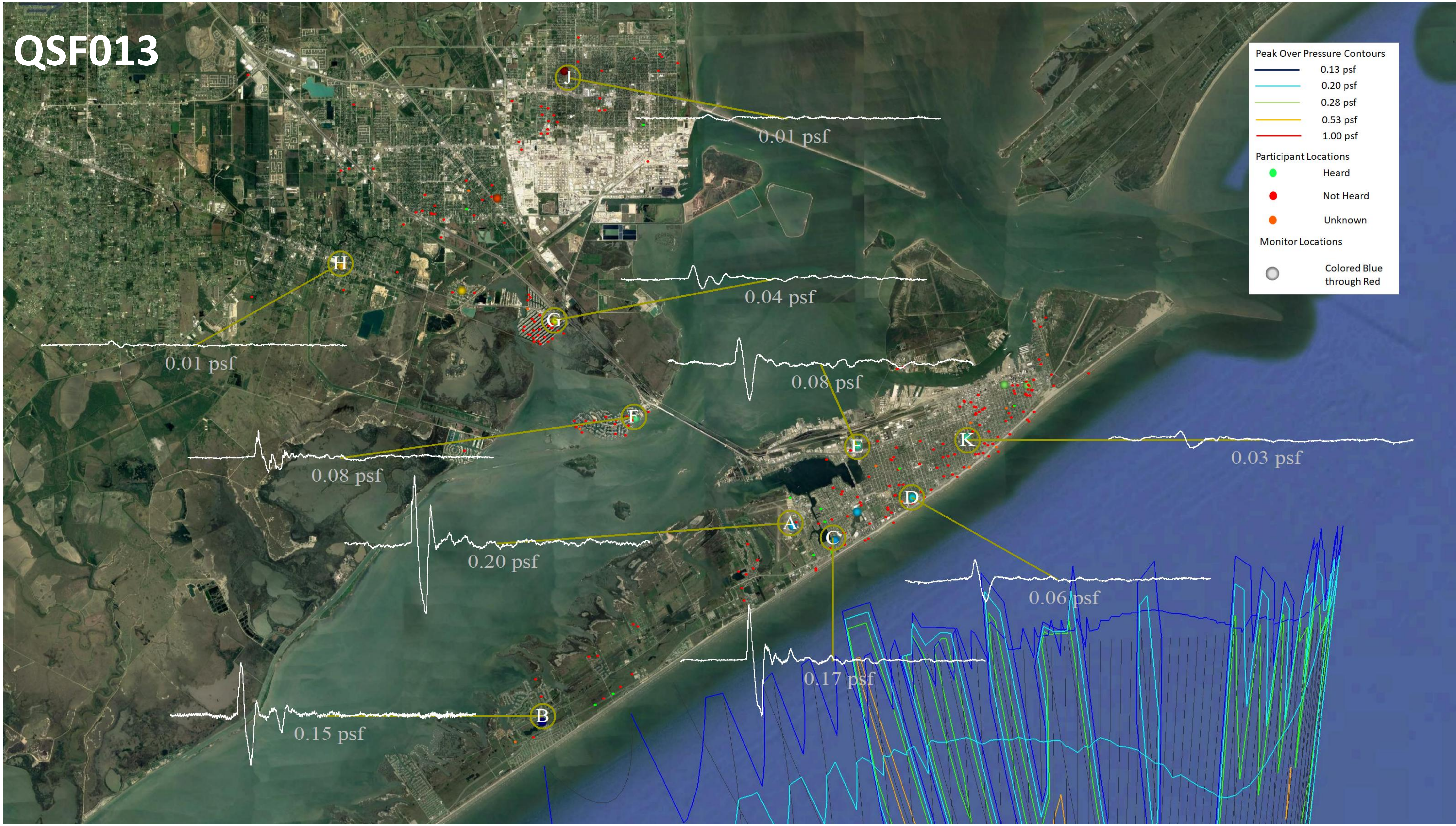
QSF009
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.01 psf
I
0.02 psf
H
0.02 psf
G
0.03 psf
0.09 psf
F
0.06 psf
E
K
0.13 psf
D
A
C
0.12 psf
0.15 psf
0.15 psf
B
0.20 psf

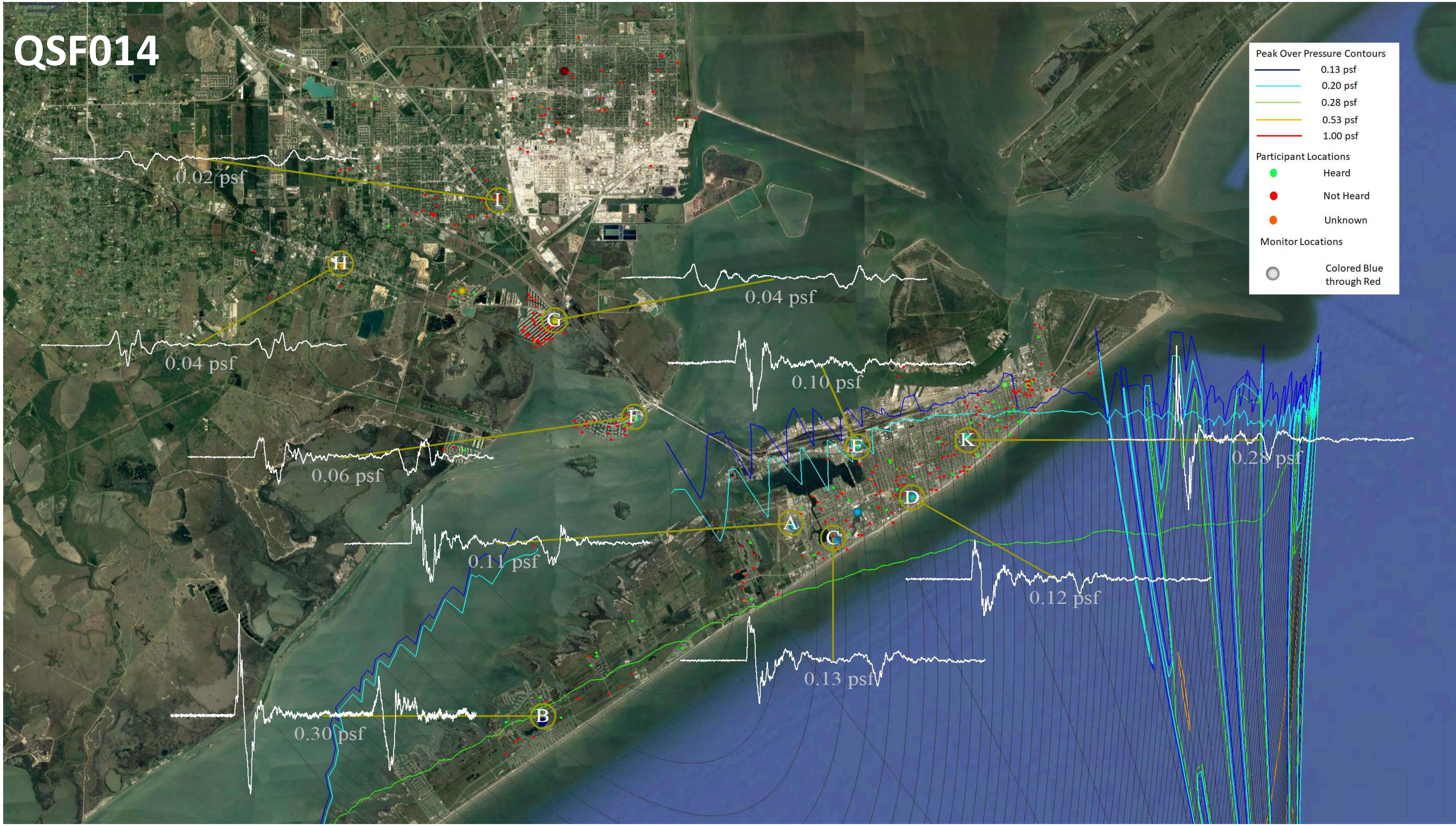


QSF010
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
0.07 psf
0.05 psf
0.10 psf
0.11 psf
0.12 psf
0.12 psf
0.15 psf
A
B
C
D
E
F
K


QSF011
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
F
0.05 psf
0.07 psf
E
K
0.10 psf
D
A
C
0.11 psf
0.12 psf
0.12 psf
B
0.15 psf


QSF012
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
0.01 psf
0.03 psf
0.07 psf
0.03 psf
0.11 psf
0.11 psf
0.12 psf
0.11 psf
0.11 psf
I
G
F
E
K
D
A
C
B

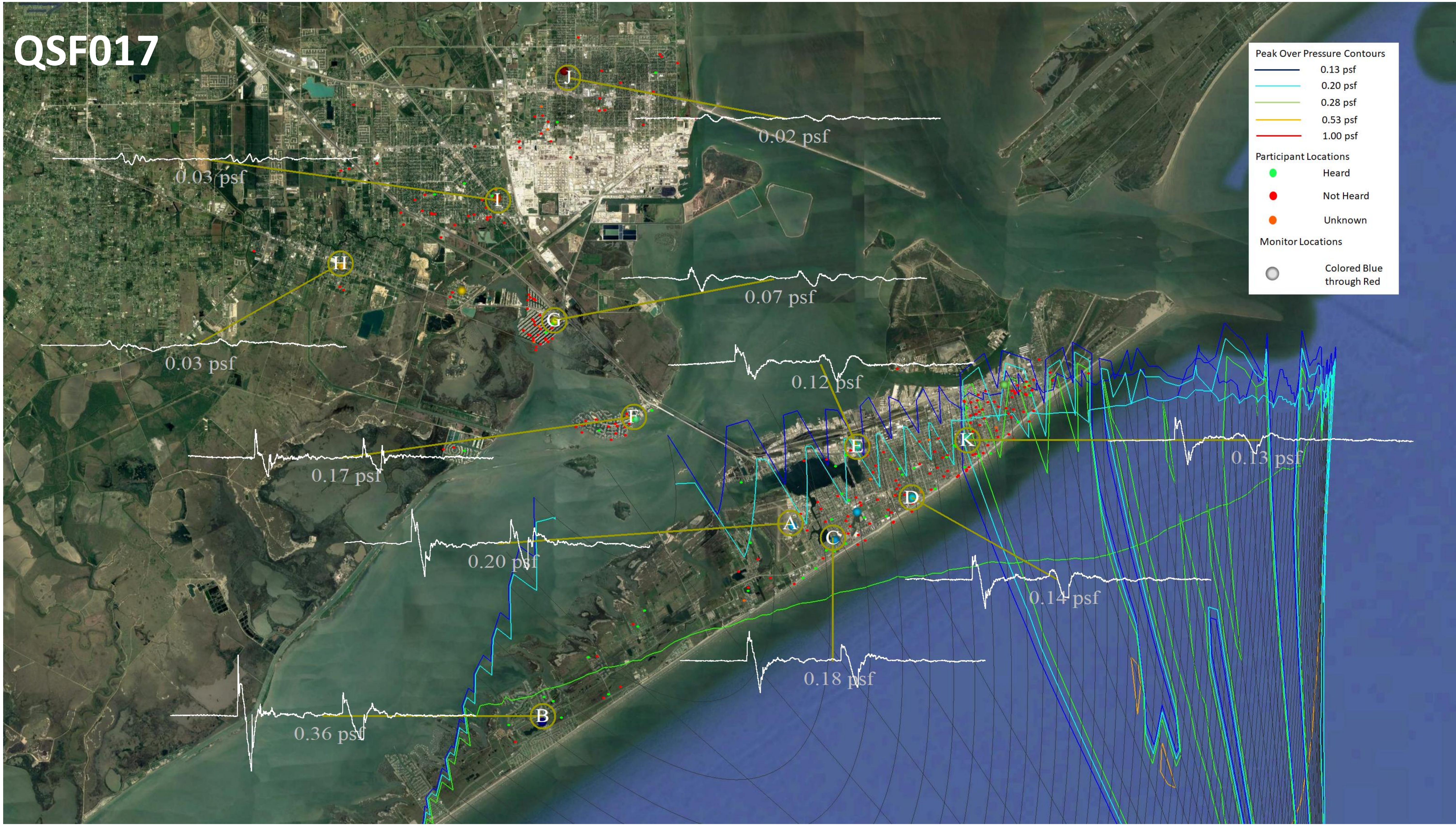

QSF013
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
0.01 psf
0.04 psf
0.01 psf
0.08 psf
0.08 psf
0.03 psf
0.20 psf
0.06 psf
0.17 psf
0.15 psf
A
B
C
D
E
F
G
H
J
K



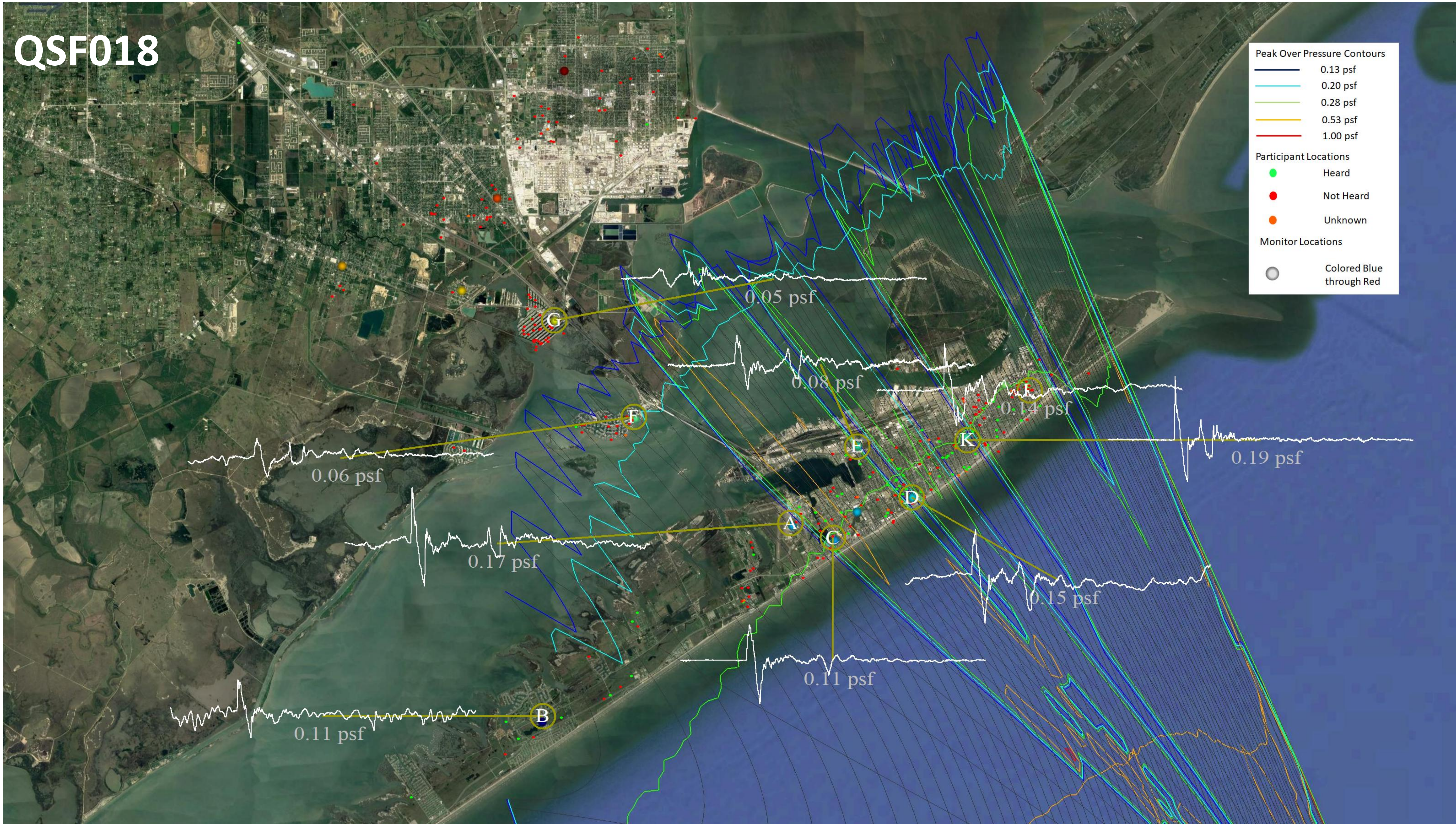
QSF014
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
0.02 psf
I
H
0.04 psf
G
0.04 psf
0.10 psf
F
0.06 psf
E
K
0.28 psf
D
A
C
0.11 psf
0.12 psf
0.13 psf
B
0.30 psf

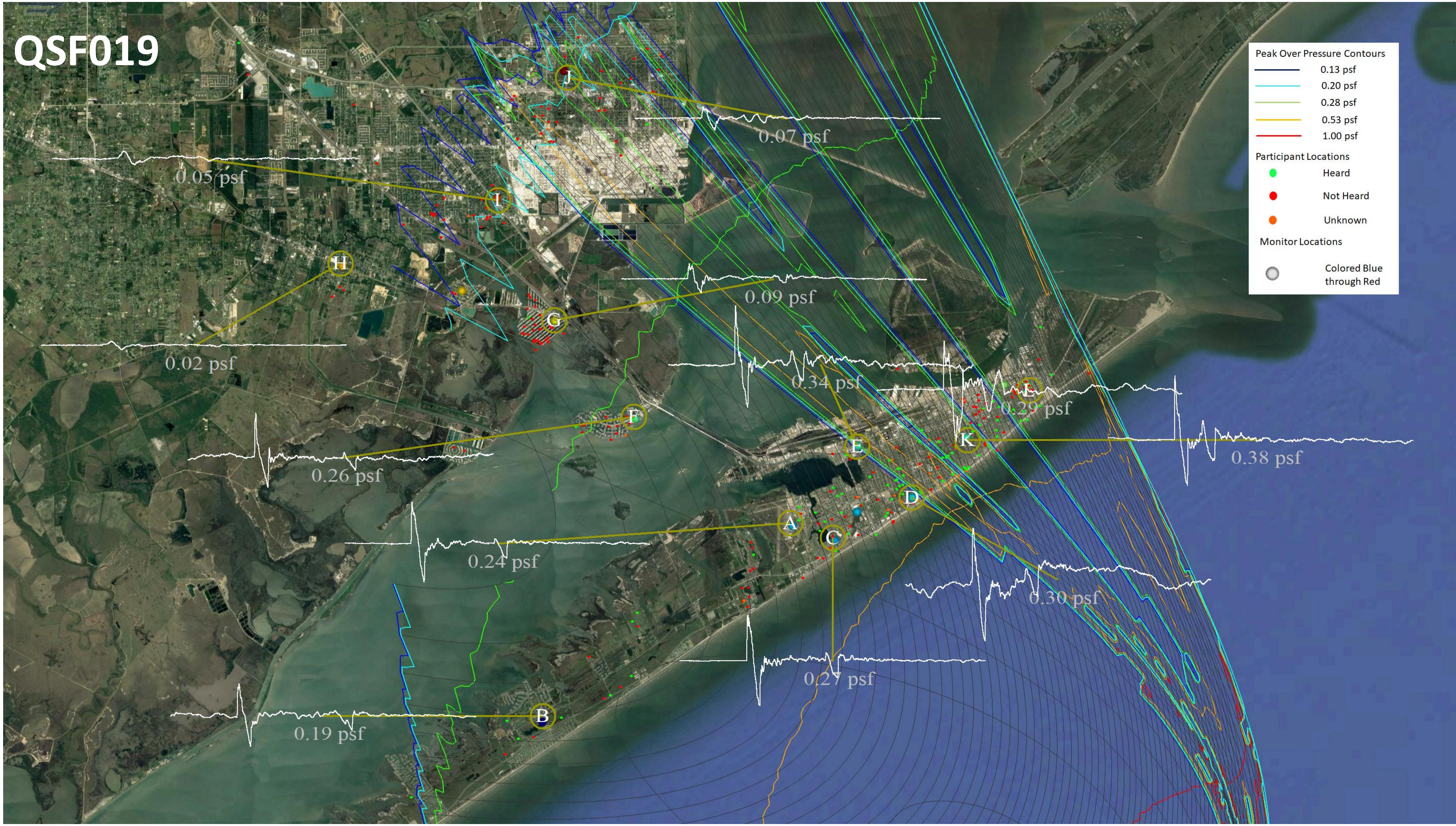

QSF015
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
I
0.03 psf
H
0.02 psf
G
0.05 psf
0.03 psf
F
0.06 psf
E
K
0.03 psf
D
A
C
0.07 psf
0.08 psf
0.08 psf
B
0.08 psf

QSF016
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.02 psf
I
0.03 psf
H
0.05 psf
G
0.07 psf
0.26 psf
F
0.17 psf
E
K
0.29 psf
D
A
C
0.23 psf
0.40 psf
0.22 psf
B
0.24 psf

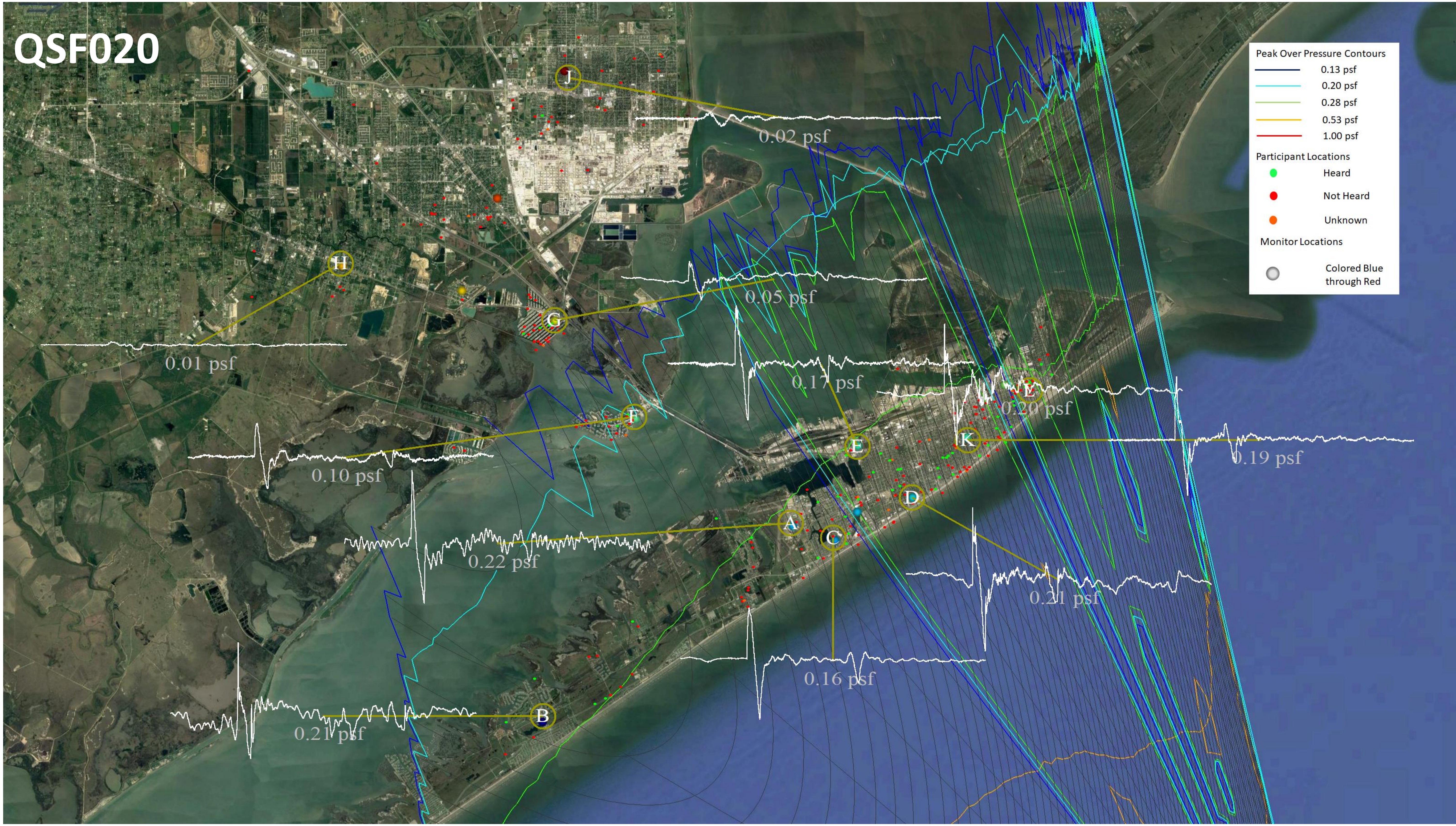


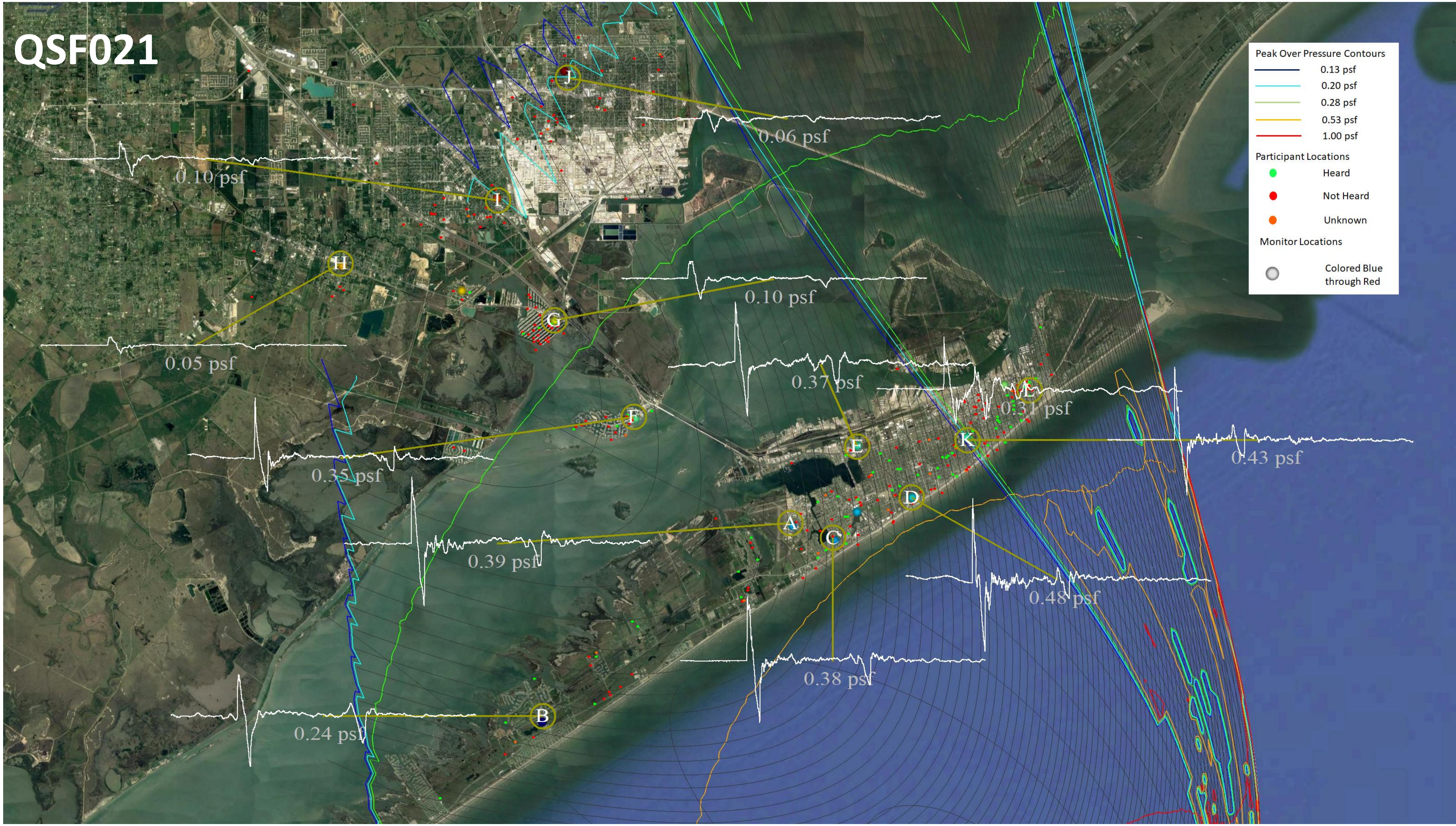
QSF017
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.02 psf
I
0.03 psf
H
0.03 psf
G
0.07 psf
0.12 psf
F
0.17 psf
E
K
0.13 psf
D
A
C
0.20 psf
0.14 psf
0.18 psf
B
0.36 psf

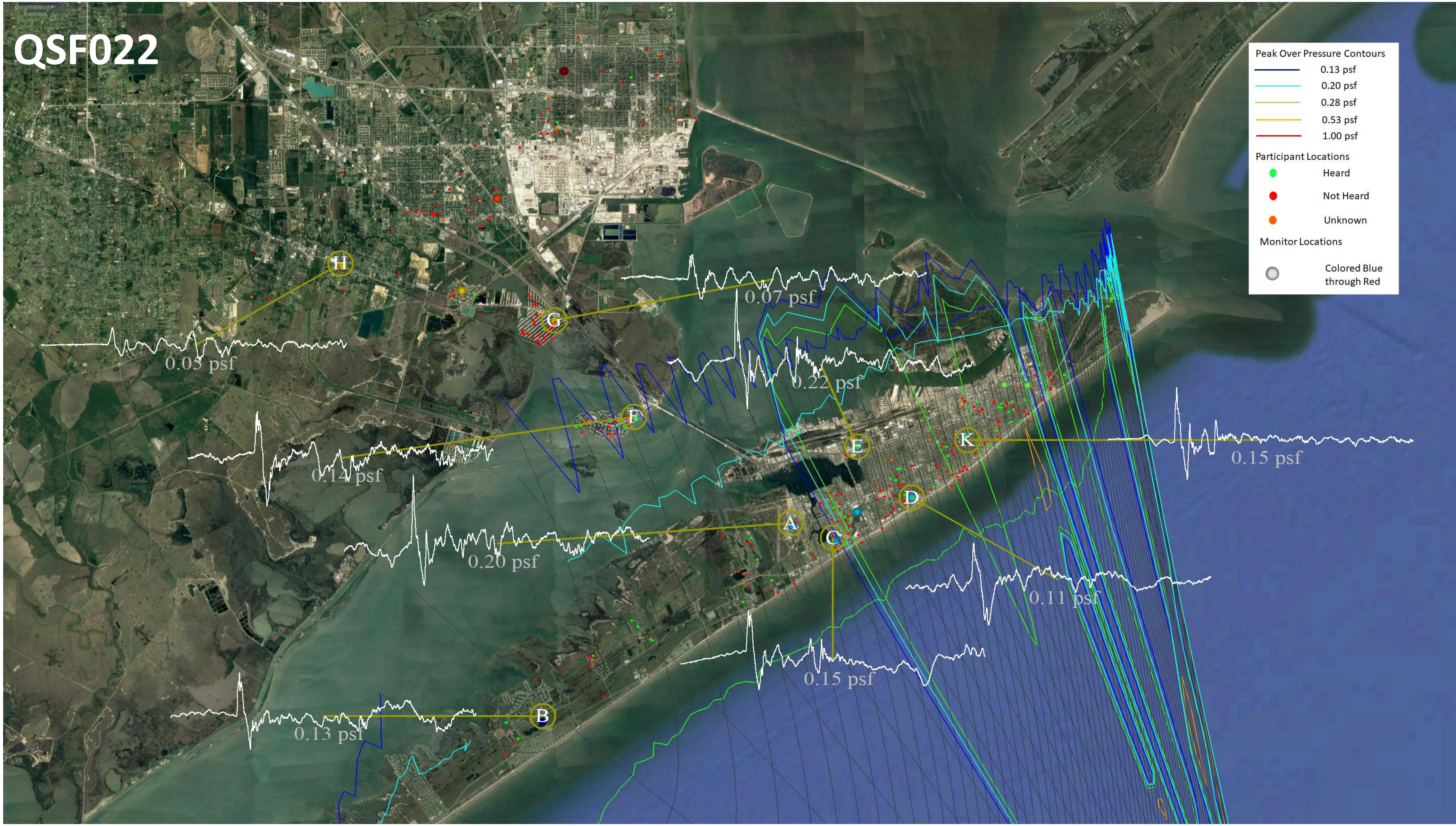

QSF018
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
G
0.05 psf
0.08 psf
L
0.14 psf
F
E
K
0.19 psf
0.06 psf
D
A
C
0.17 psf
0.15 psf
0.11 psf
B
0.11 psf



QSF019
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.07 psf
I
0.05 psf
H
0.02 psf
G
0.09 psf
0.34 psf
L
0.29 psf
K
0.38 psf
F
0.26 psf
E
D
A
C
0.24 psf
0.30 psf
0.27 psf
B
0.19 psf

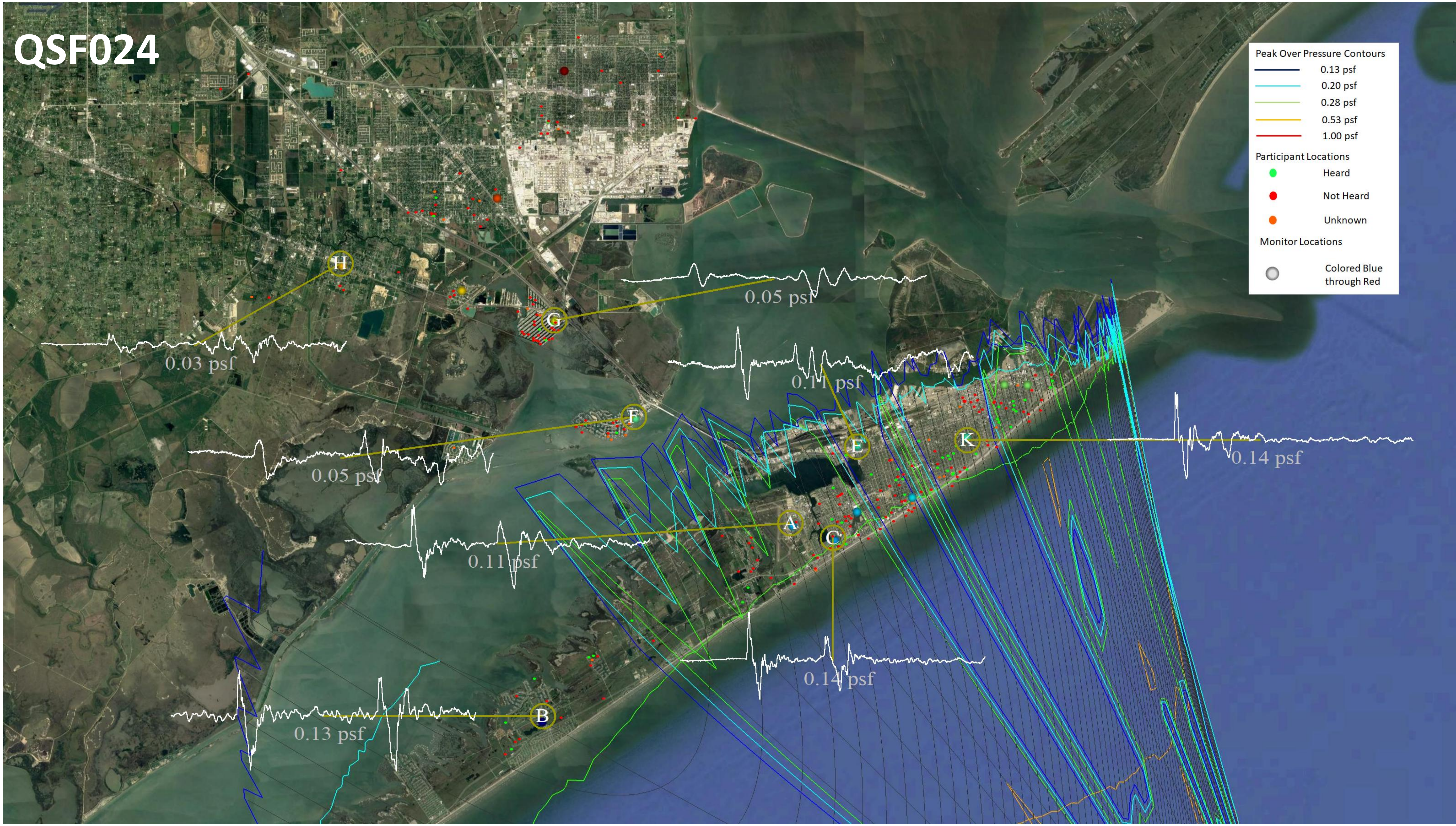

QSF020
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.02 psf
H
0.01 psf
G
0.05 psf
0.17 psf
F
0.10 psf
L
0.20 psf
K
0.19 psf
E
D
A
C
0.22 psf
0.21 psf
0.16 psf
B
0.21 psf

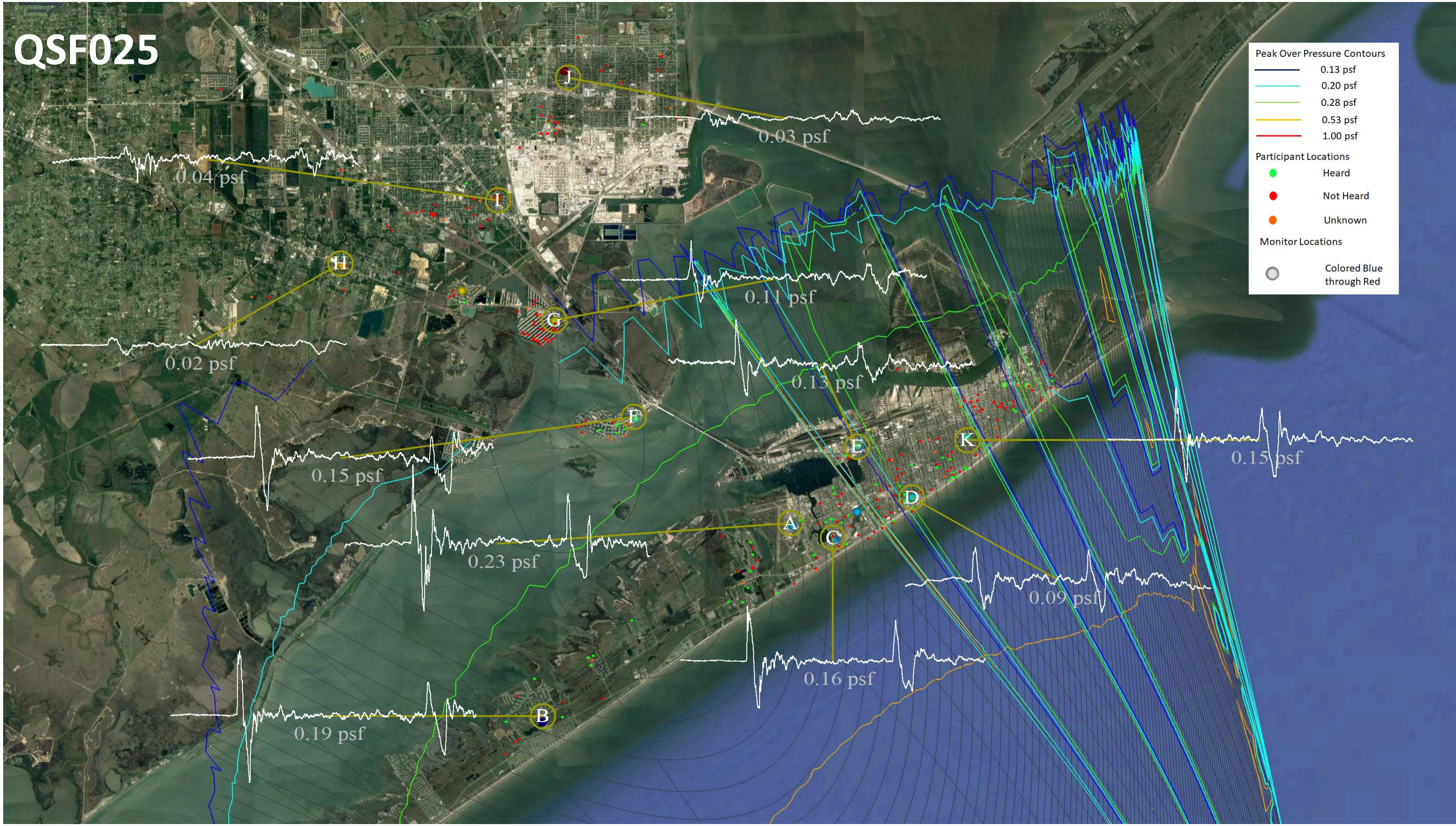

QSF021
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
A
B
C
D
E
F
G
H
I
J
K
L
0.06 psf
0.10 psf
0.10 psf
0.05 psf
0.37 psf
0.31 psf
0.43 psf
0.35 psf
0.39 psf
0.48 psf
0.38 psf
0.24 psf



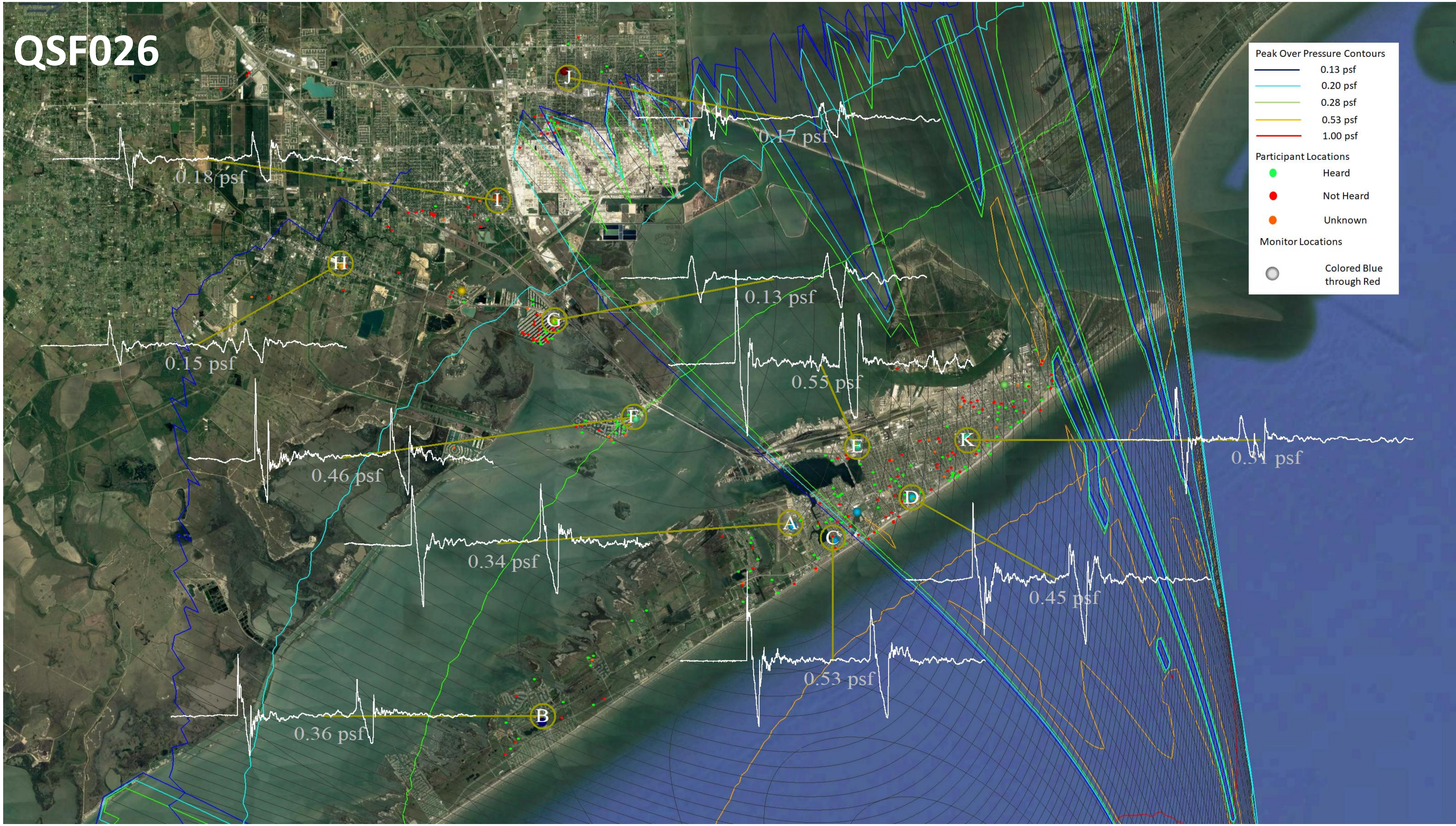
QSF022
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
0.07 psf
0.05 psf
0.22 psf
0.14 psf
0.15 psf
0.20 psf
0.11 psf
0.15 psf
0.13 psf
A
B
C
D
E
F
G
H
K

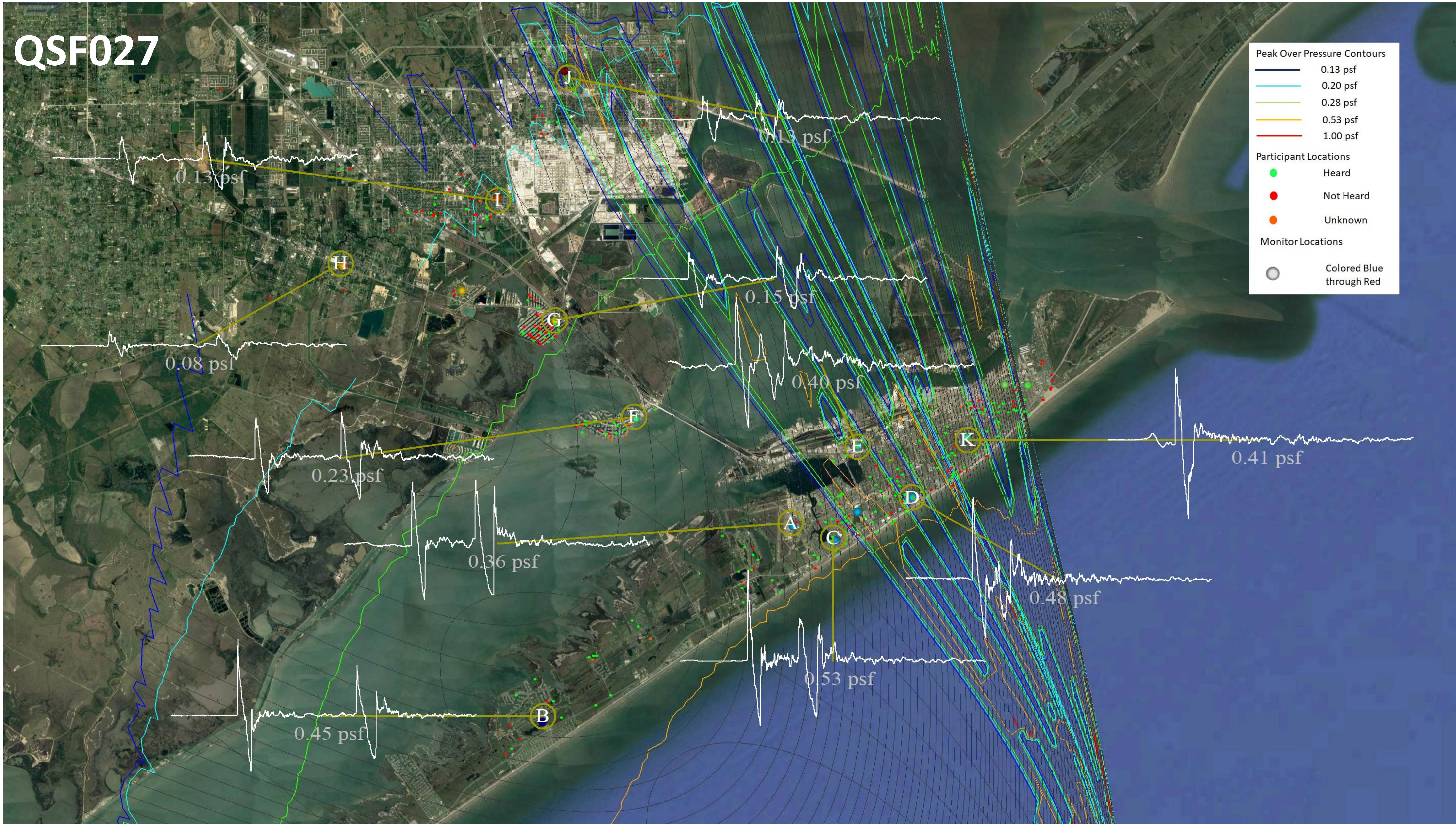

QSF023
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.03 psf
H
0.04 psf
G
0.04 psf
0.22 psf
E
K
0.16 psf
D
A
C
0.17 psf
0.24 psf
0.17 psf
B
0.14 psf


QSF024
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
H
G
F
E
K
A
C
B
0.03 psf
0.05 psf
0.11 psf
0.05 psf
0.11 psf
0.14 psf
0.14 psf
0.13 psf

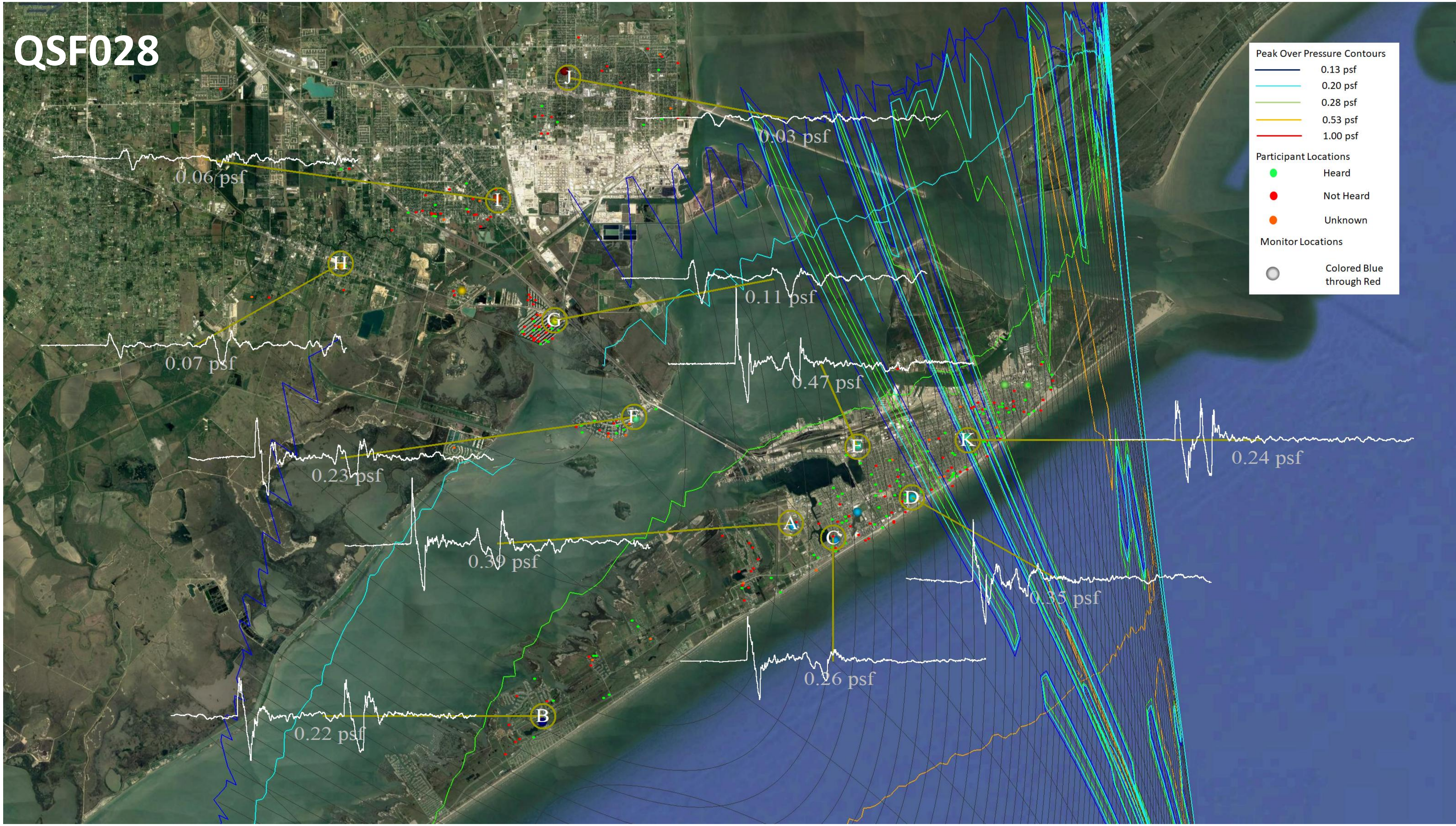


QSF025
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.03 psf
I
0.04 psf
H
0.02 psf
G
0.11 psf
0.13 psf
F
0.15 psf
E
K
0.15 psf
D
A
C
0.23 psf
0.09 psf
0.16 psf
B
0.19 psf

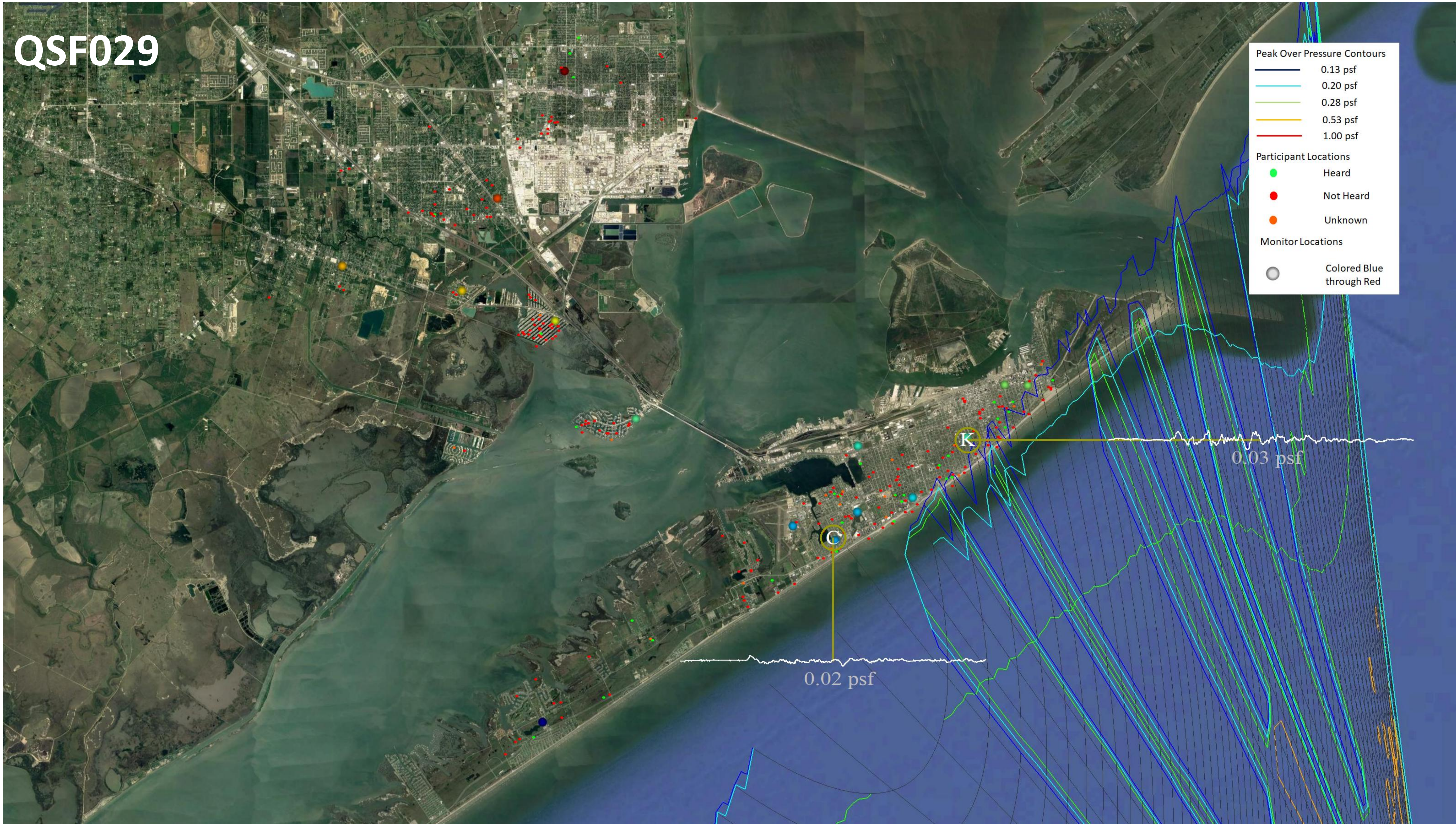

QSF026
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.17 psf
0.18 psf
I
H
0.13 psf
G
0.15 psf
0.55 psf
F
E
K
0.46 psf
0.51 psf
D
A
C
0.34 psf
0.45 psf
0.53 psf
B
0.36 psf

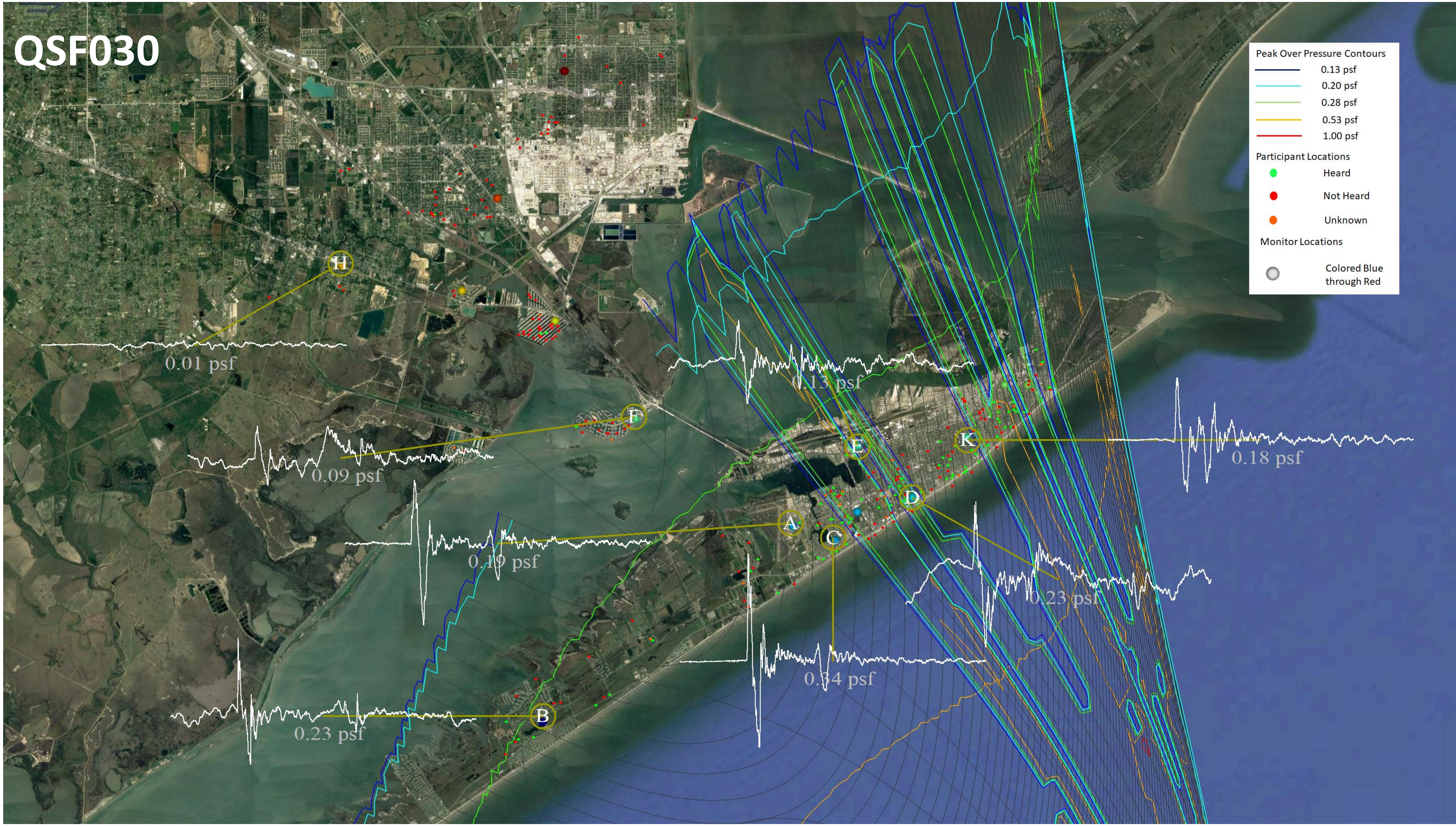


QSF027
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.13 psf
I
0.13 psf
H
0.08 psf
G
0.15 psf
0.40 psf
F
0.23 psf
E
K
0.41 psf
D
A
C
0.36 psf
0.48 psf
0.53 psf
B
0.45 psf

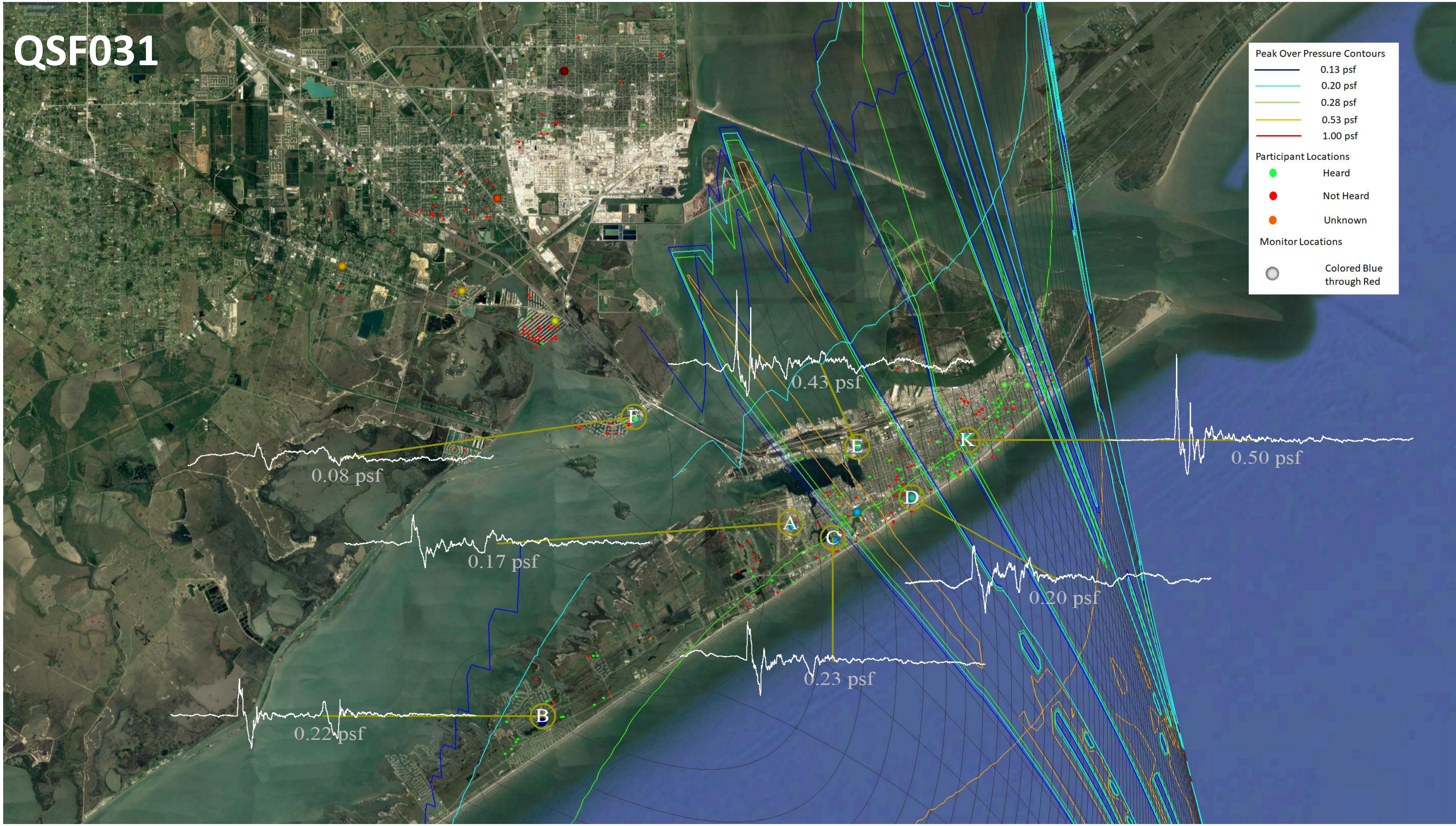


QSF028
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.03 psf
I
0.06 psf
H
0.07 psf
G
0.11 psf
0.47 psf
F
0.23 psf
E
K
0.24 psf
D
A
C
0.39 psf
0.35 psf
0.26 psf
B
0.22 psf

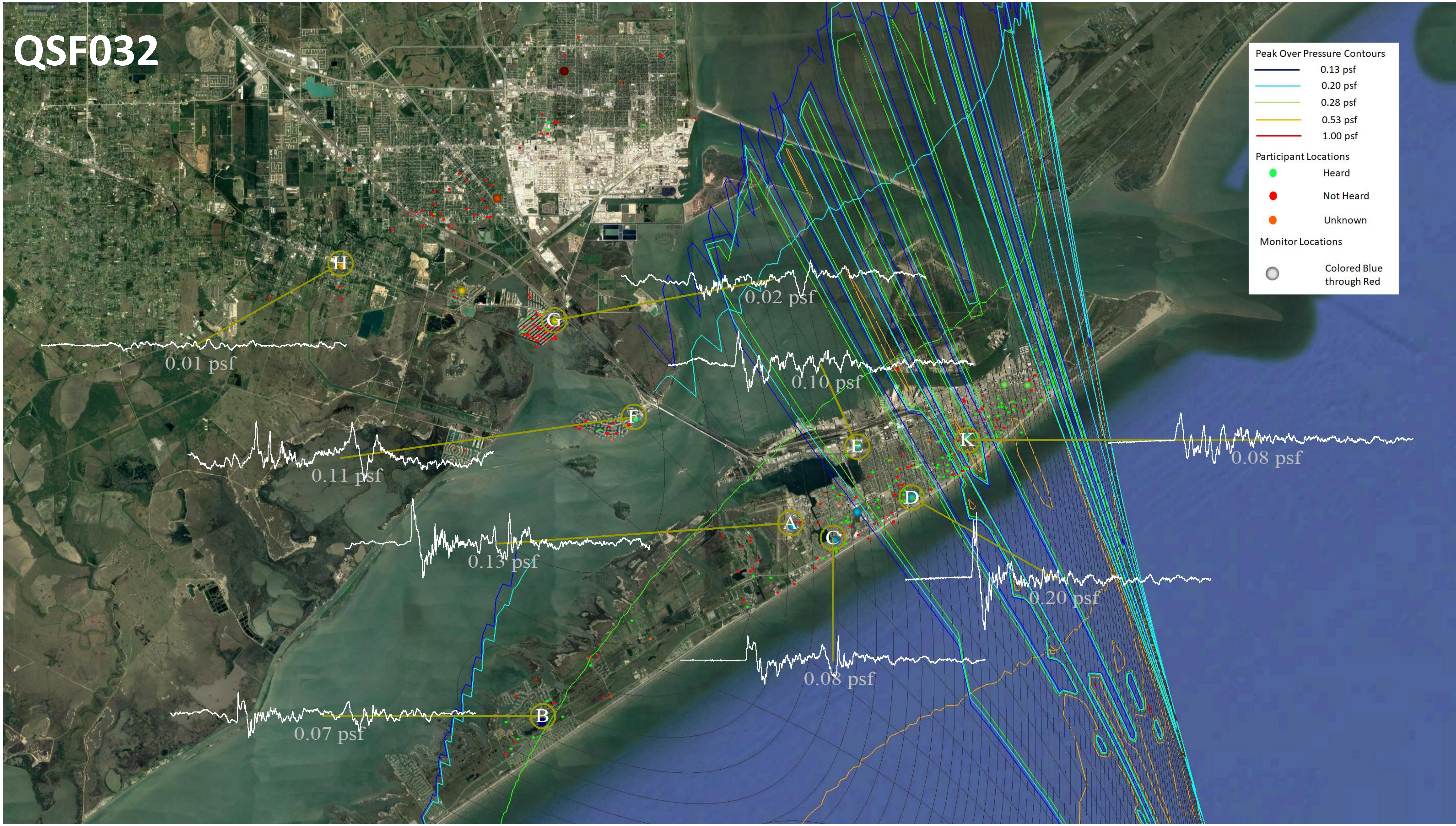

QSF029
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
K
0.03 psf
C
0.02 psf



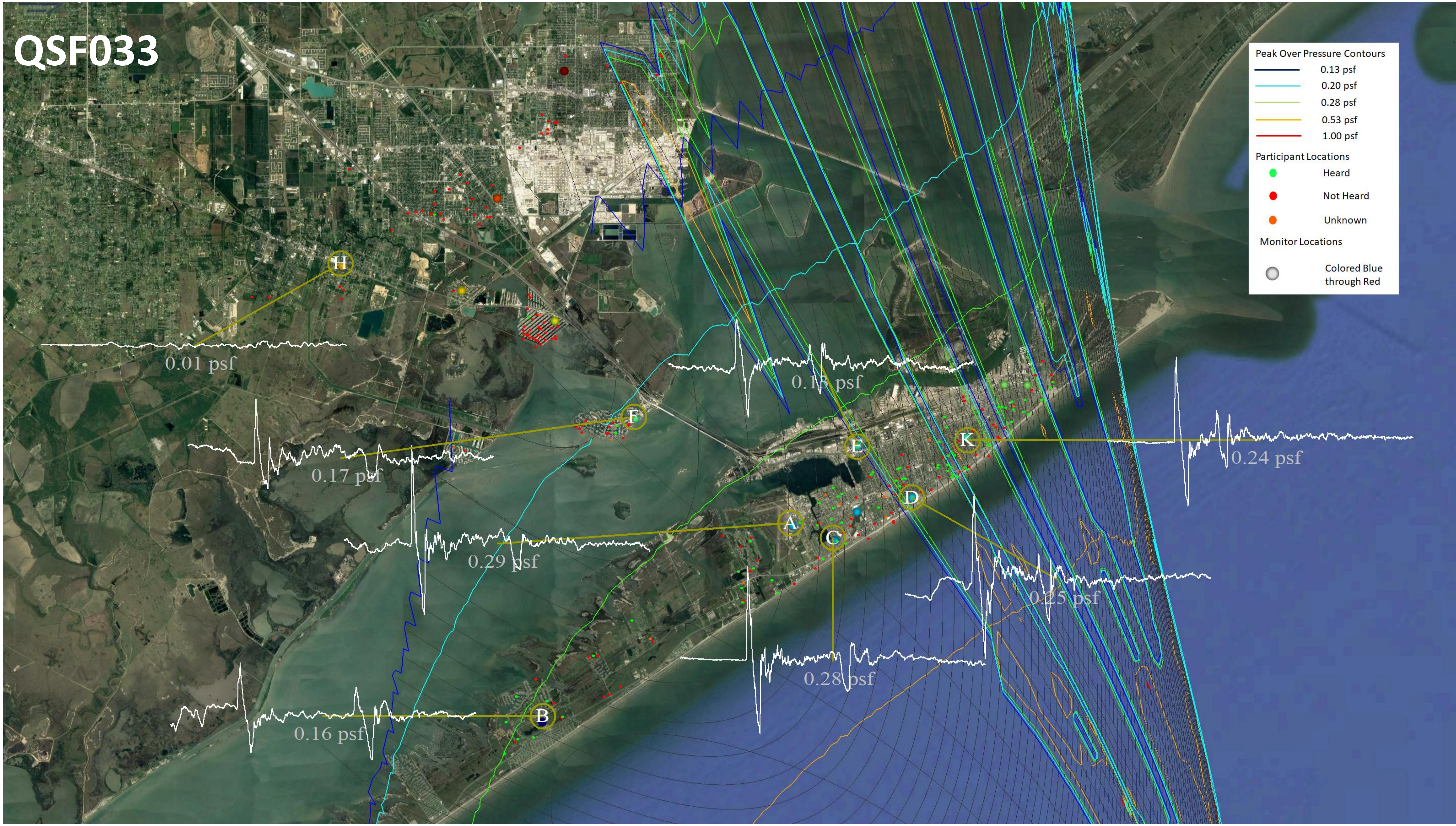
QSF030
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
H
0.01 psf
F
0.09 psf
0.13 psf
E
K
0.18 psf
D
A
C
0.19 psf
0.23 psf
0.34 psf
B
0.23 psf



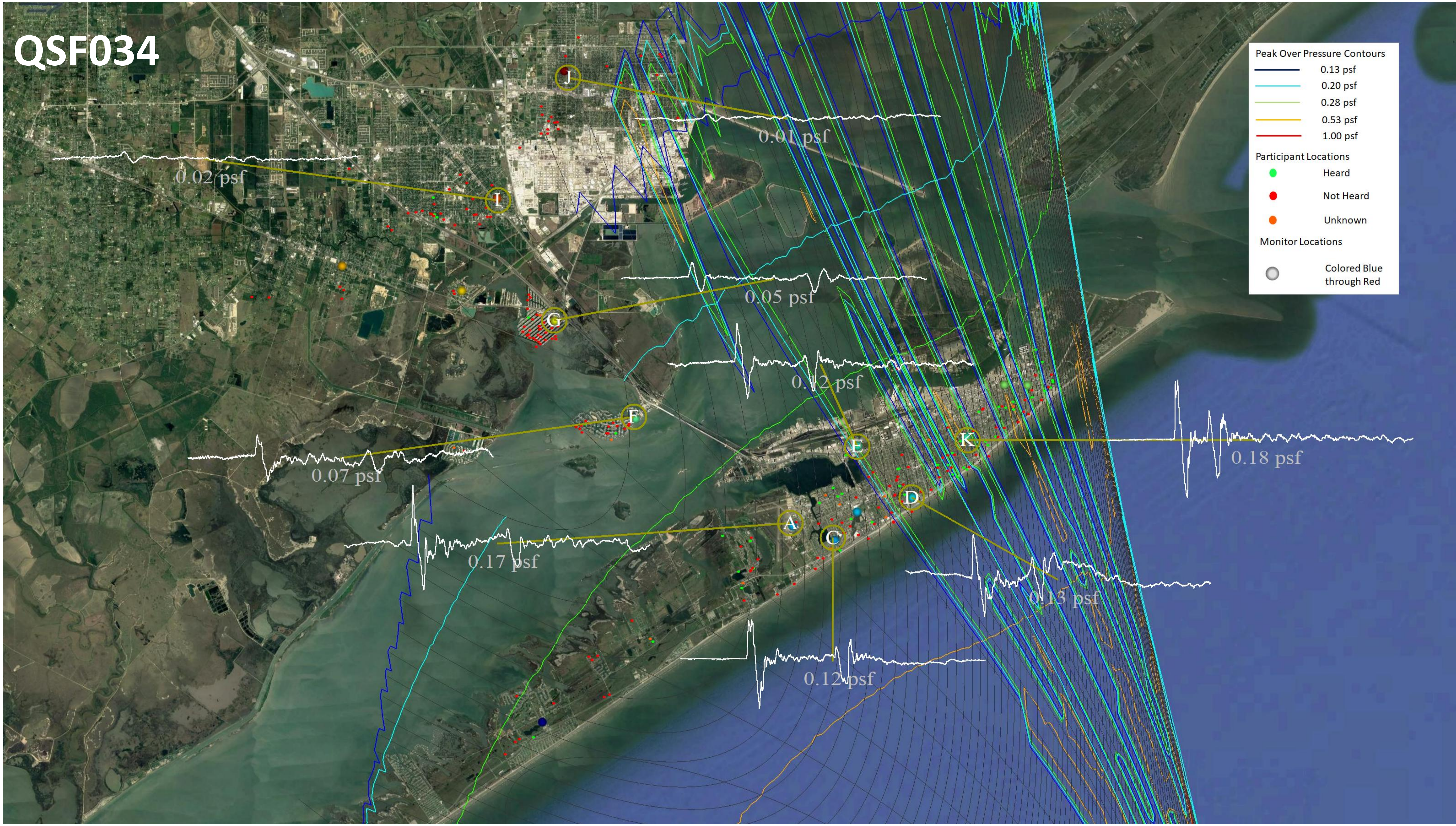
QSF031
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
0.43 psf
0.08 psf
0.50 psf
0.17 psf
0.20 psf
0.23 psf
0.22 psf
A
B
C
D
E
F
K



QSF032
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
H
G
F
E
K
D
A
C
B
0.01 psf
0.02 psf
0.10 psf
0.11 psf
0.08 psf
0.13 psf
0.20 psf
0.08 psf
0.07 psf

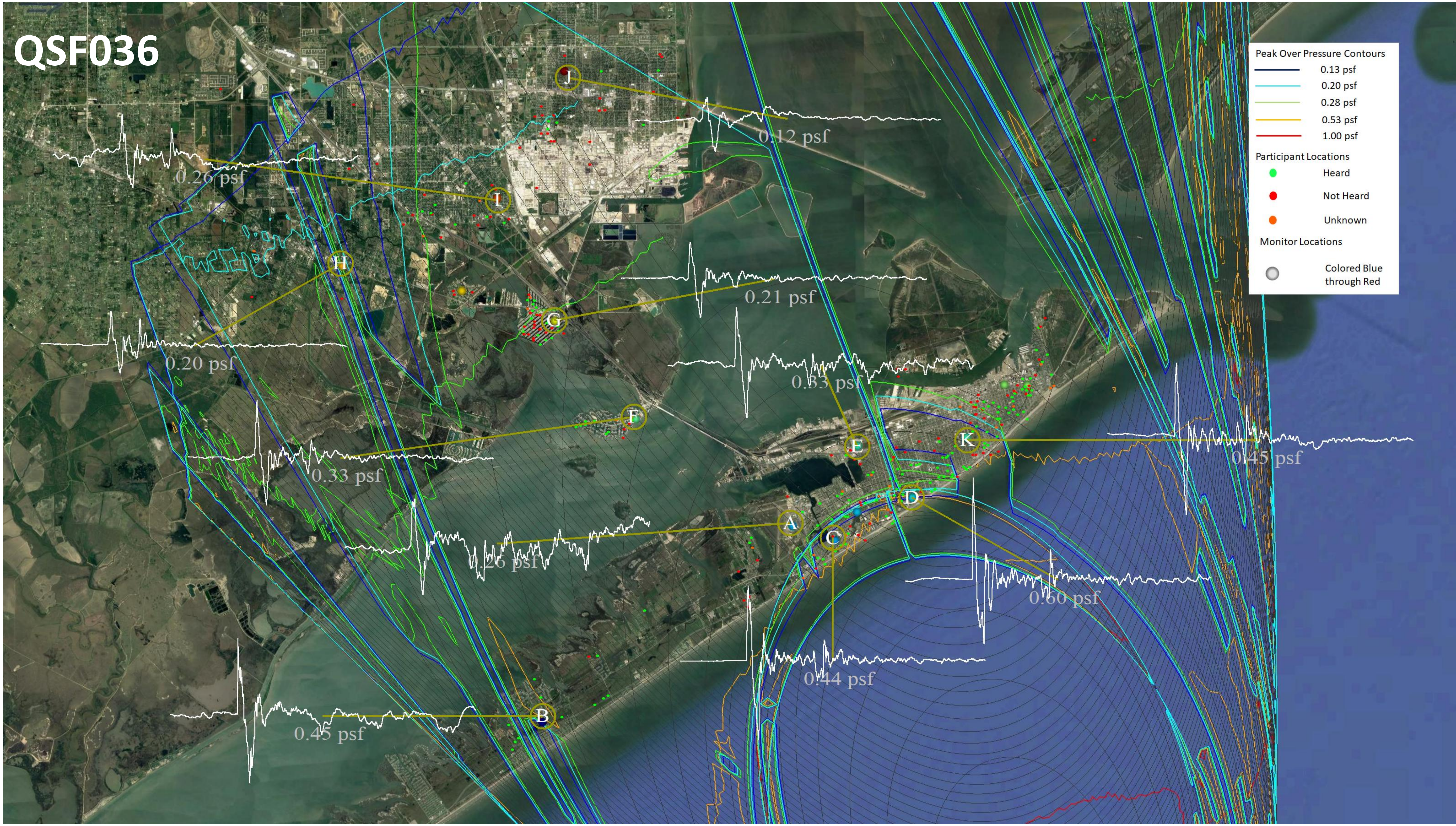


QSF033
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
H
0.01 psf
F
0.17 psf
0.13 psf
E
K
0.24 psf
D
A
C
0.29 psf
0.25 psf
0.28 psf
B
0.16 psf

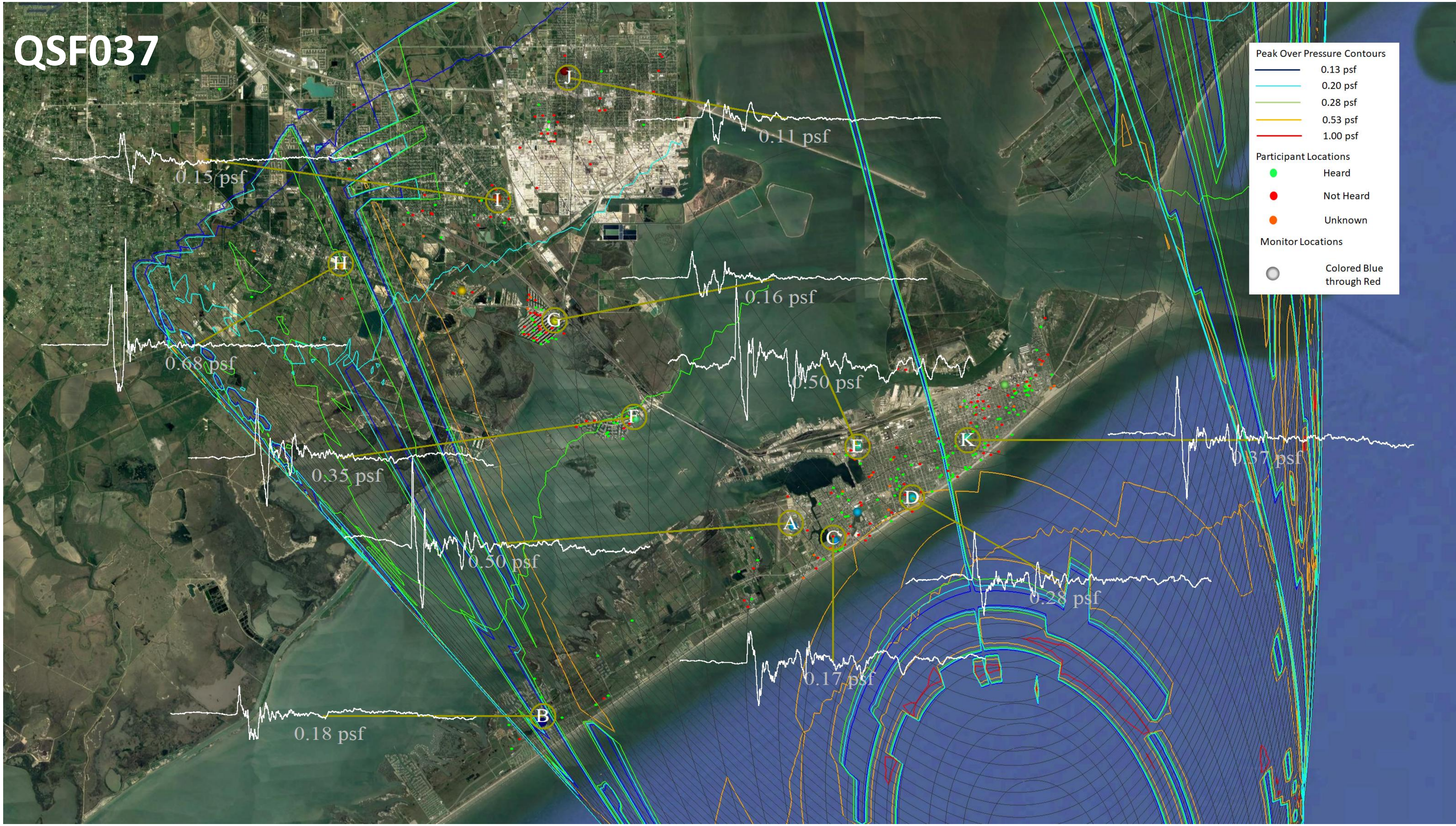


QSF034
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.01 psf
I
0.02 psf
G
0.05 psf
0.12 psf
F
0.07 psf
E
K
0.18 psf
D
A
C
0.17 psf
0.13 psf
0.12 psf


QSF035
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.03 psf
G
0.11 psf
0.37 psf
F
0.59 psf
E
K
0.19 psf
D
A
C
0.37 psf
0.20 psf
0.30 psf



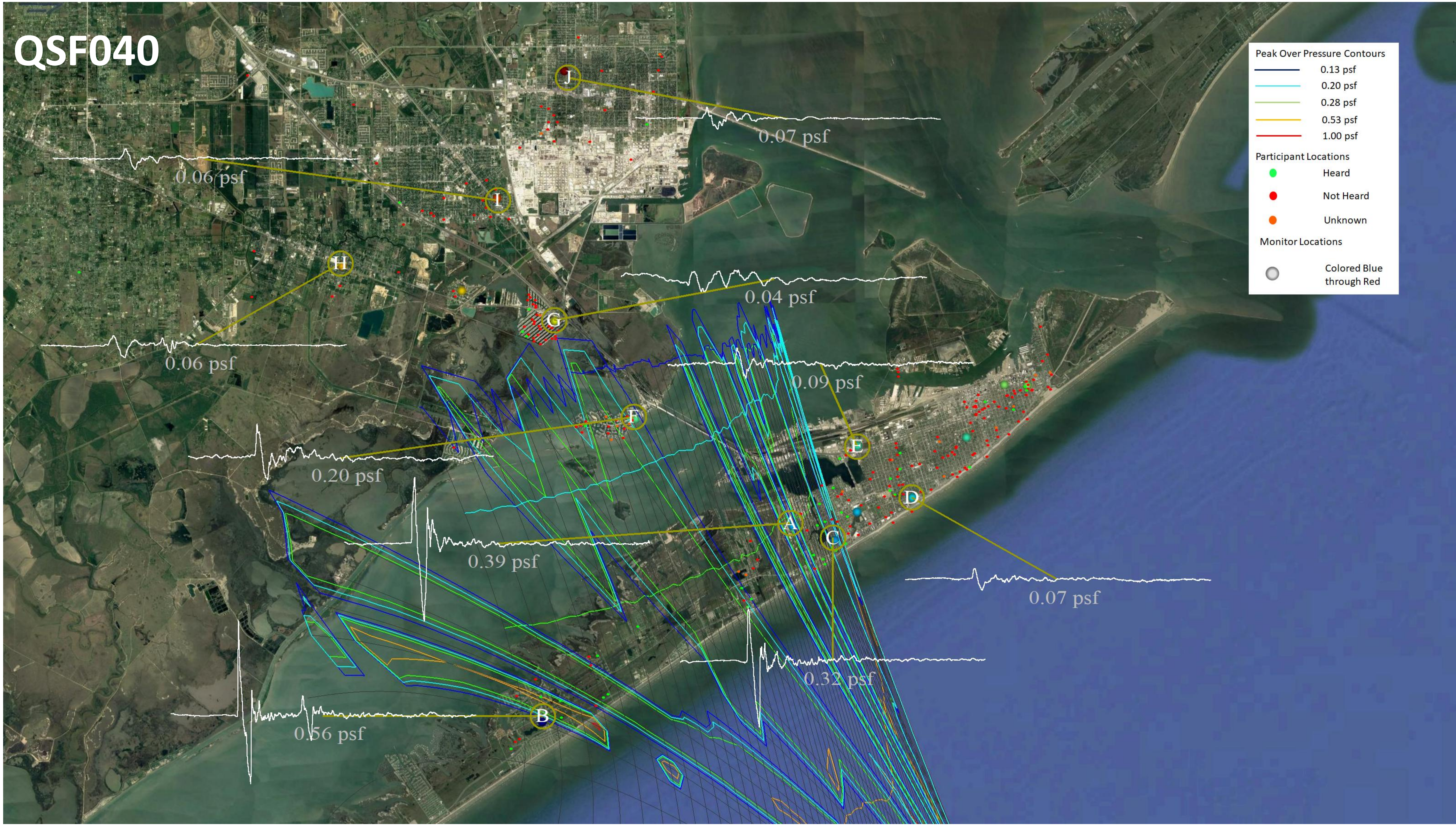
QSF036
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.12 psf
0.26 psf
I
H
0.21 psf
G
0.20 psf
0.33 psf
F
E
K
0.45 psf
0.33 psf
D
A
C
0.26 psf
0.60 psf
0.44 psf
B
0.45 psf

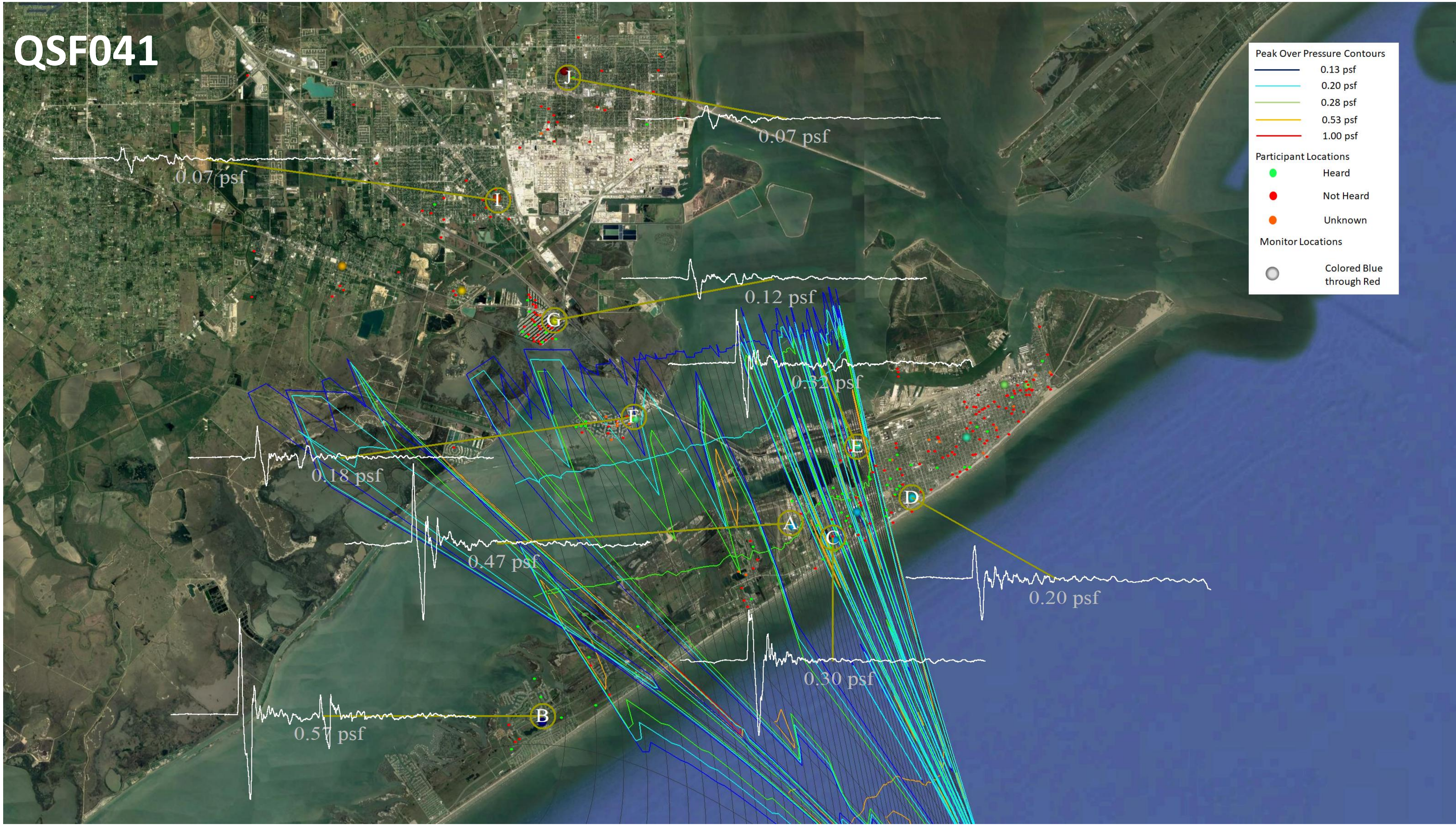


QSF037
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.11 psf
0.15 psf
I
H
G
0.16 psf
0.68 psf
0.50 psf
F
E
K
0.37 psf
0.35 psf
D
A
C
0.50 psf
0.28 psf
0.17 psf
B
0.18 psf

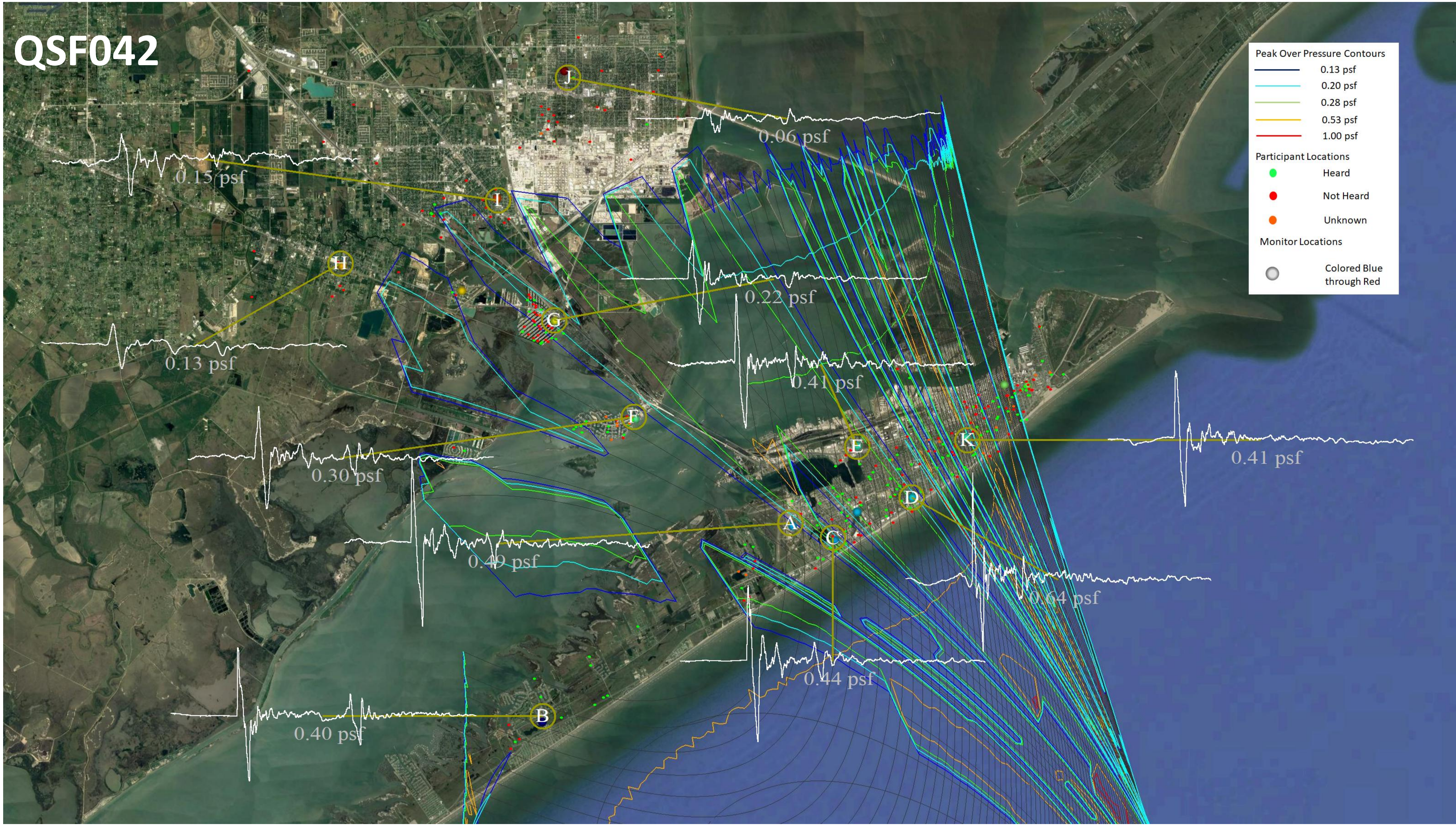

QSF038
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
0.11 psf
0.14 psf
0.23 psf
0.09 psf
0.17 psf
0.06 psf
A
B
C
D
E
K

QSF039
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.07 psf
I
0.07 psf
H
0.08 psf
G
0.11 psf
F
0.17 psf
A
0.19 psf
C
0.20 psf
D
0.15 psf
K
0.27 psf
B
0.25 psf

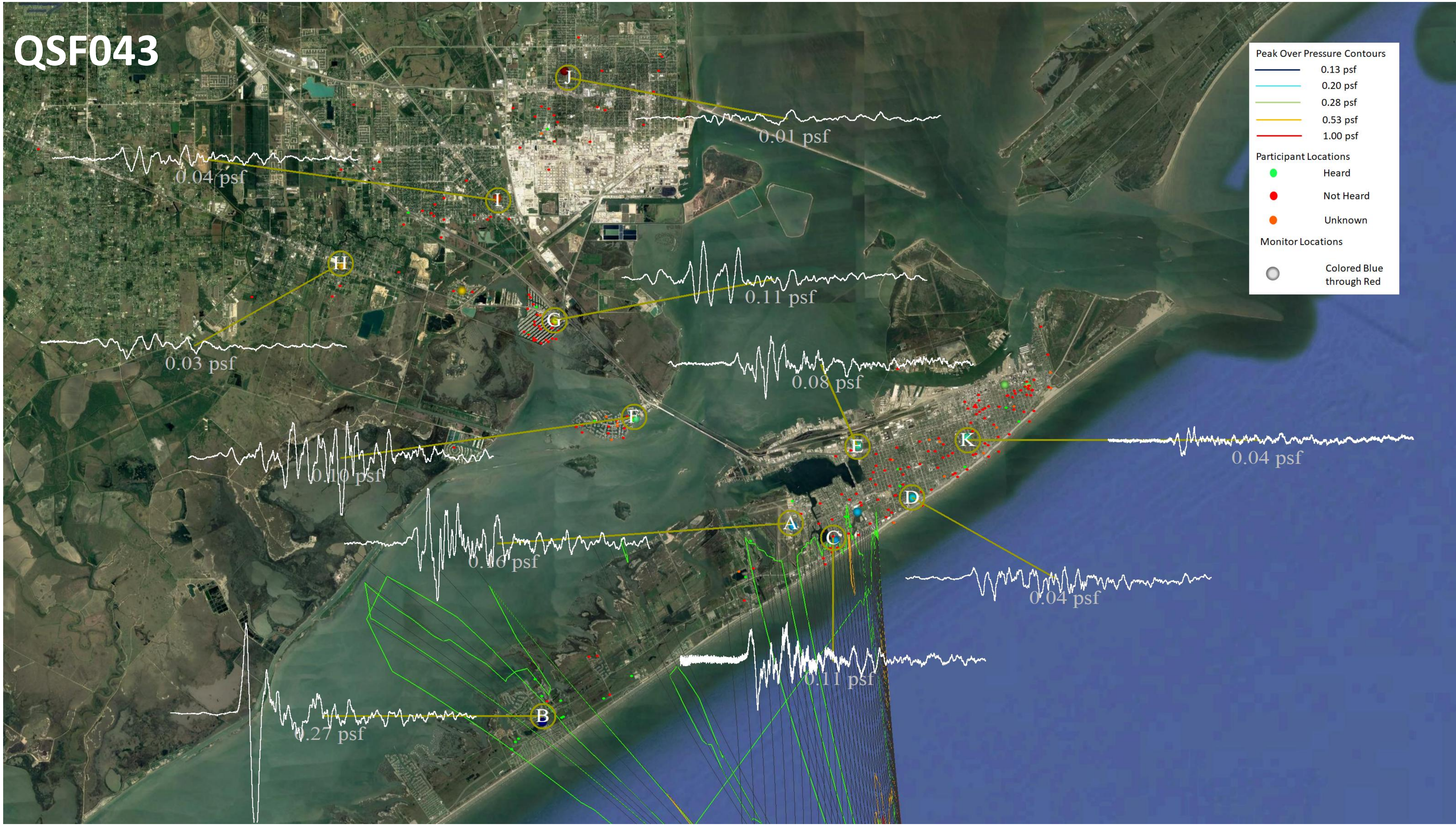

QSF040
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.07 psf
I
0.06 psf
H
0.06 psf
G
0.04 psf
0.09 psf
F
0.20 psf
E
D
A
C
0.39 psf
0.07 psf
0.32 psf
B
0.56 psf



QSF041
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.07 psf
I
0.07 psf
G
0.12 psf
0.32 psf
F
0.18 psf
E
D
A
C
0.47 psf
0.20 psf
0.30 psf
B
0.57 psf

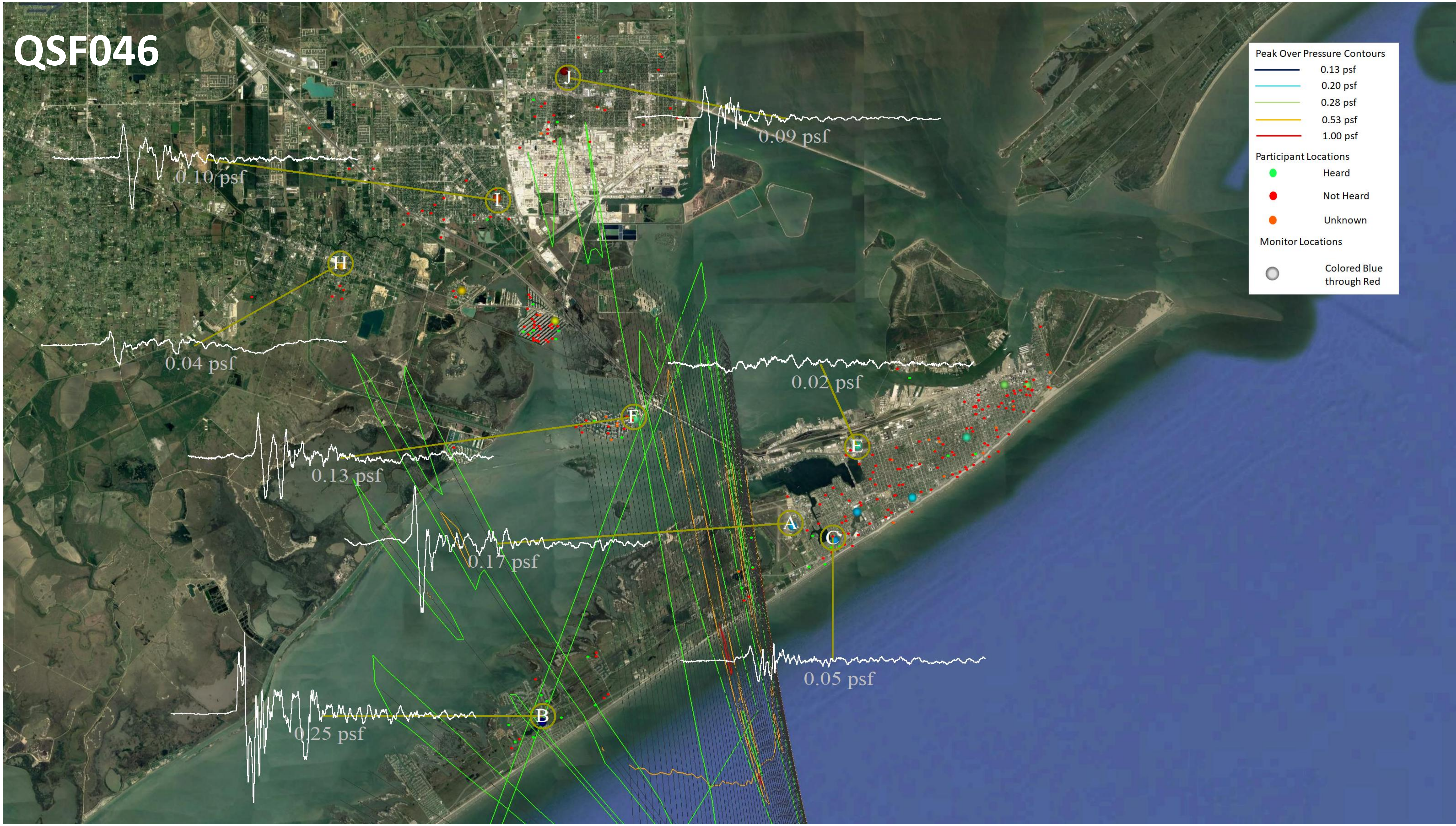


QSF042
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.06 psf
I
0.15 psf
H
0.13 psf
G
0.22 psf
0.41 psf
F
0.30 psf
E
K
0.41 psf
D
A
C
0.49 psf
0.64 psf
0.44 psf
B
0.40 psf

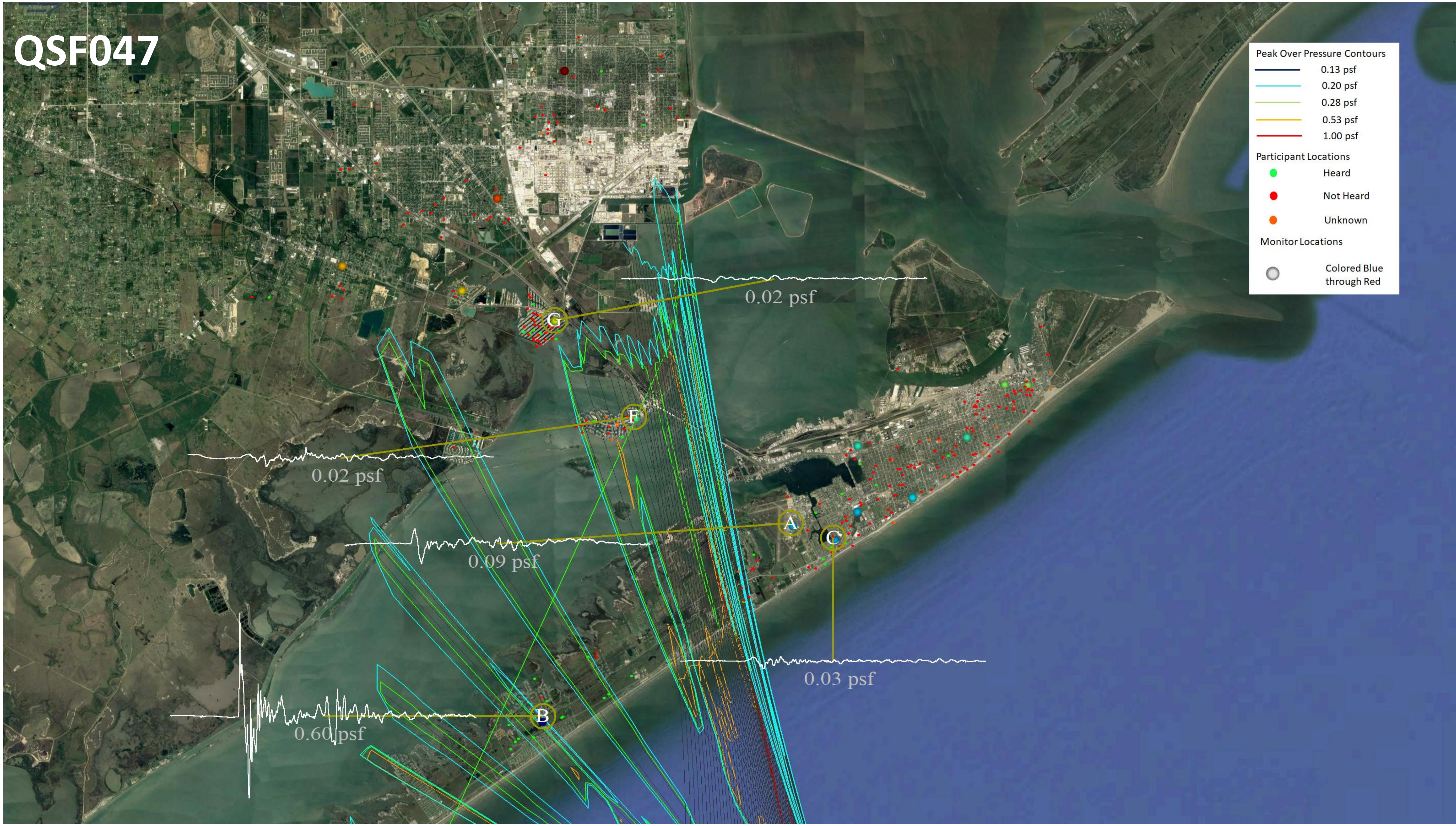

QSF043
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.01 psf
I
0.04 psf
H
0.03 psf
G
0.11 psf
0.08 psf
F
E
K
0.04 psf
D
A
C
0.04 psf
B
0.27 psf
0.11 psf

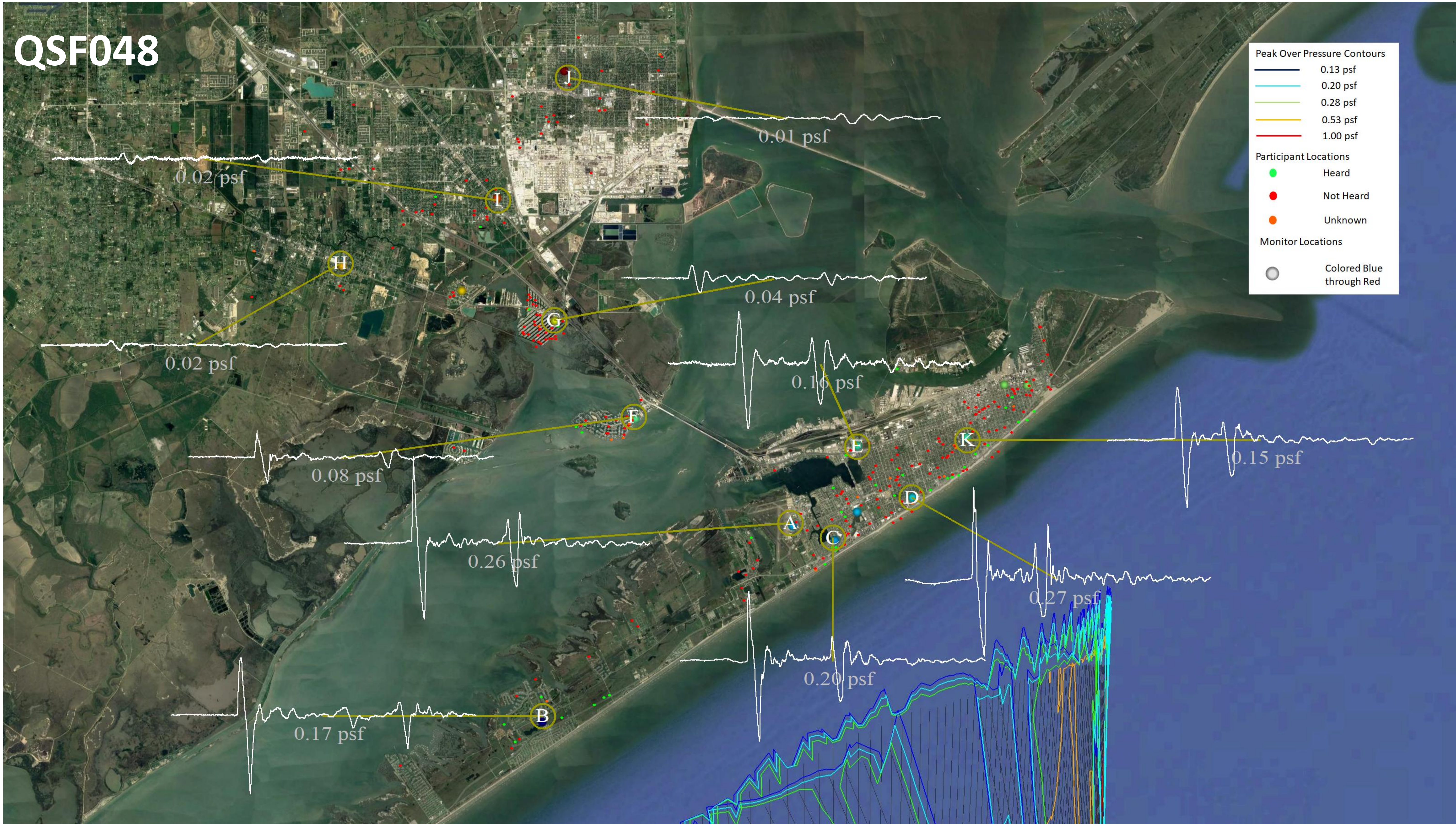
QSF044
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
A
B
C
D
E
F
G
H
I
J
K
0.05 psf
0.05 psf
0.03 psf
0.02 psf
0.03 psf
0.09 psf
0.02 psf
0.13 psf
0.03 psf
0.08 psf
0.08 psf

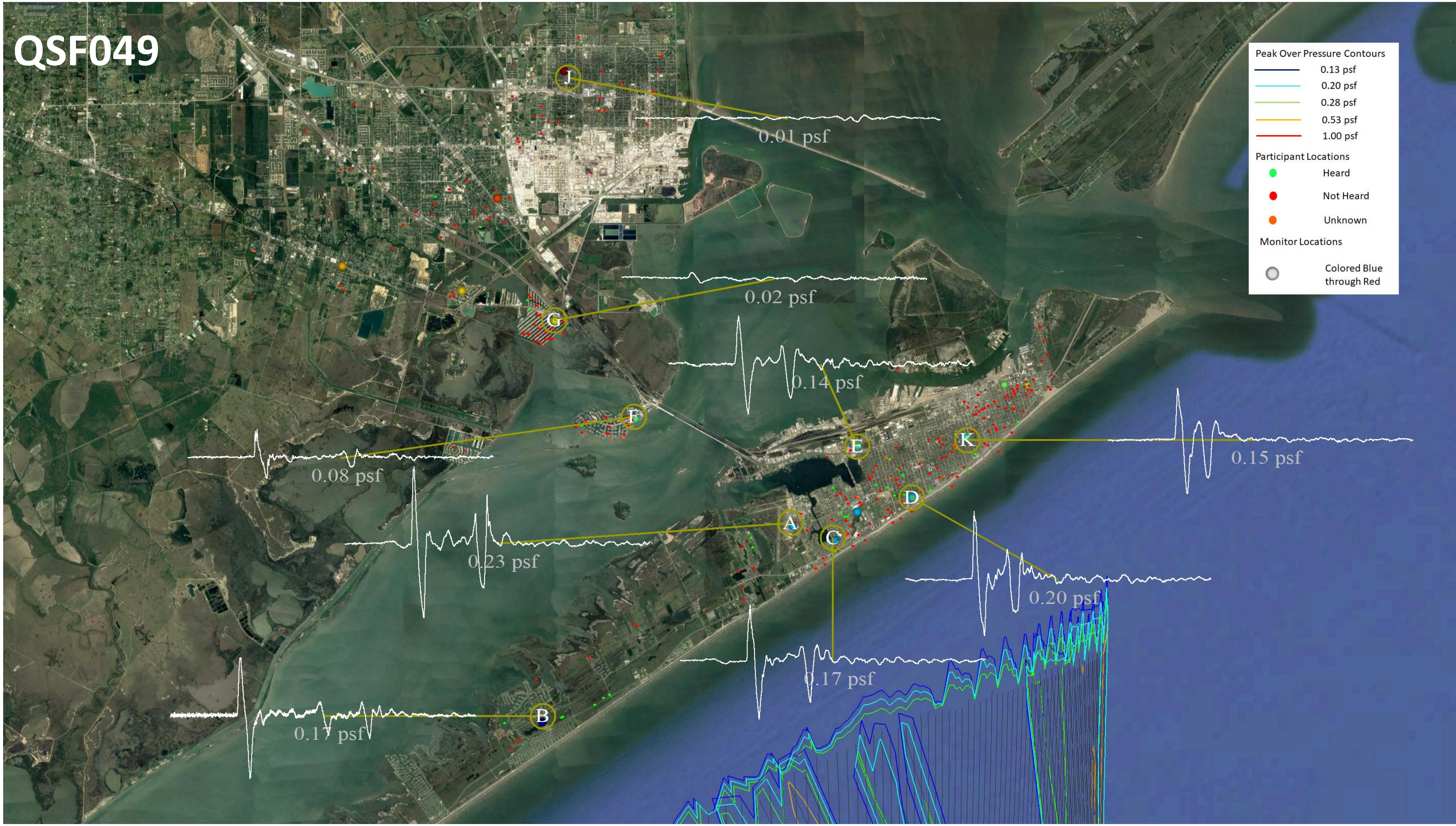
QSF045
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.04 psf
I
0.02 psf
H
0.04 psf
G
0.03 psf
F
0.05 psf
E
0.03 psf
D
0.02 psf
A
0.09 psf
C
0.05 psf
B
0.14 psf

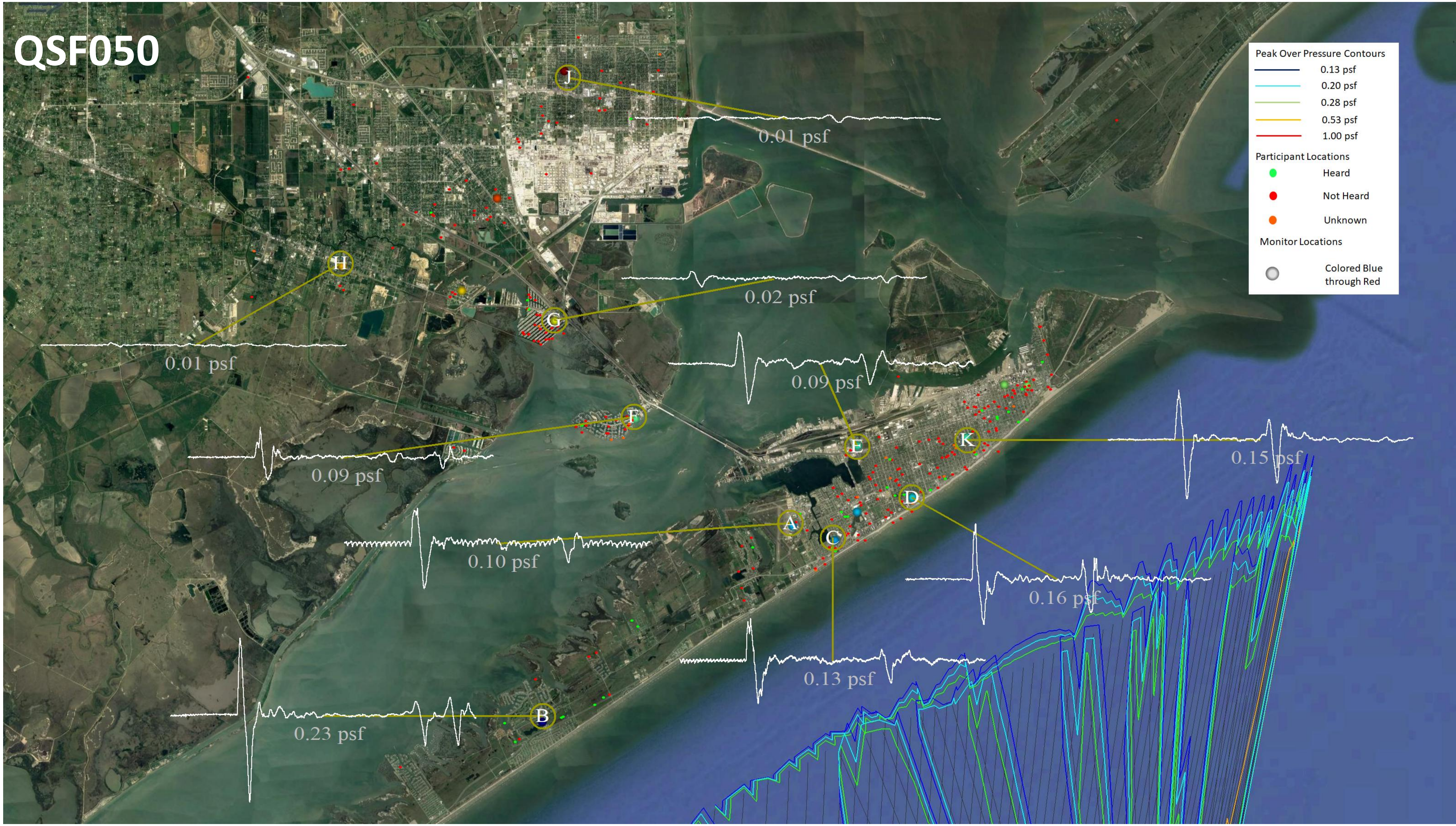


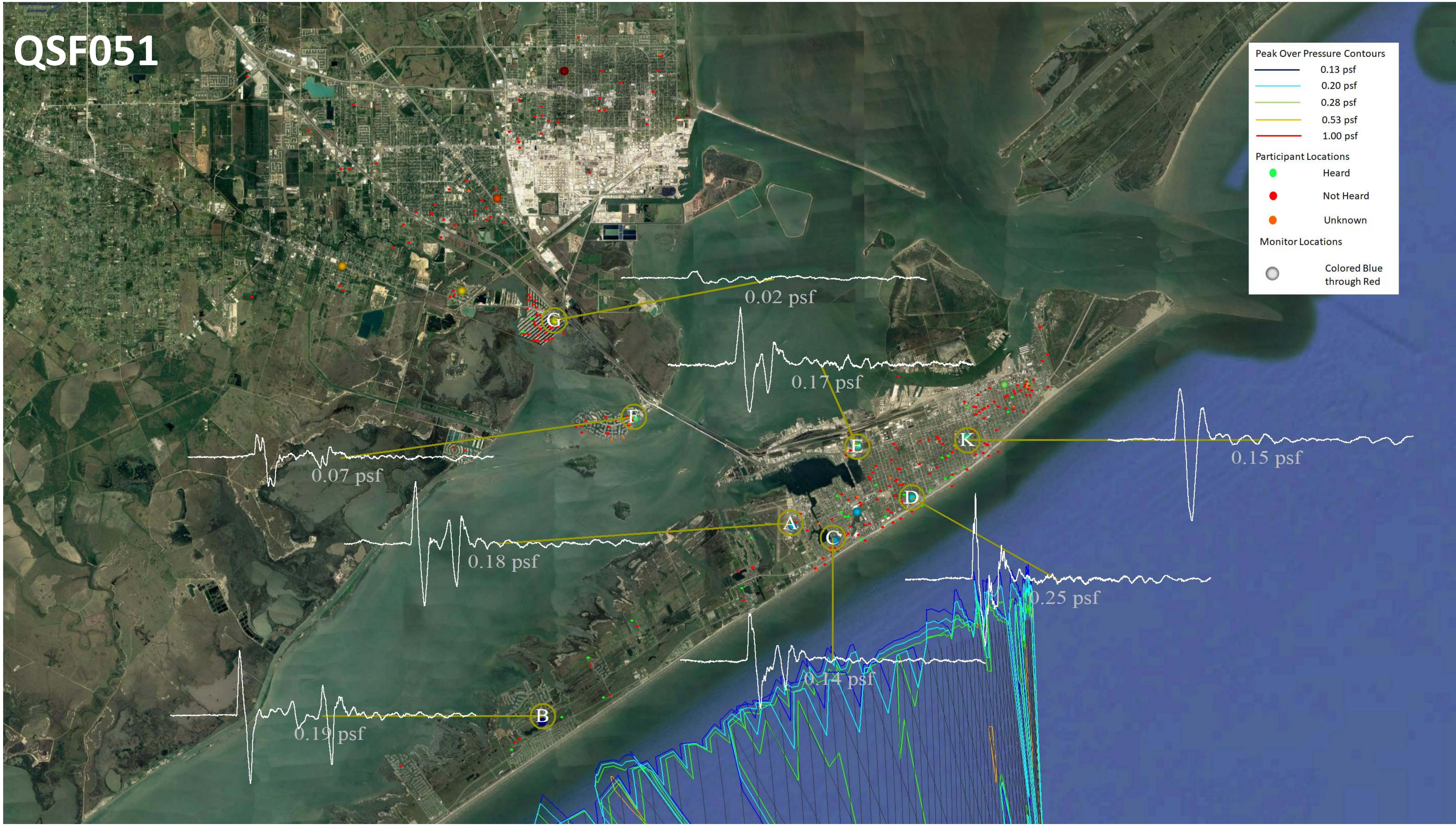
QSF046
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.09 psf
0.10 psf
I
H
0.04 psf
0.02 psf
F
E
0.13 psf
A
C
0.17 psf
0.05 psf
B
0.25 psf


QSF047
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
0.02 psf
0.02 psf
0.09 psf
0.03 psf
0.60 psf
G
F
A
C
B

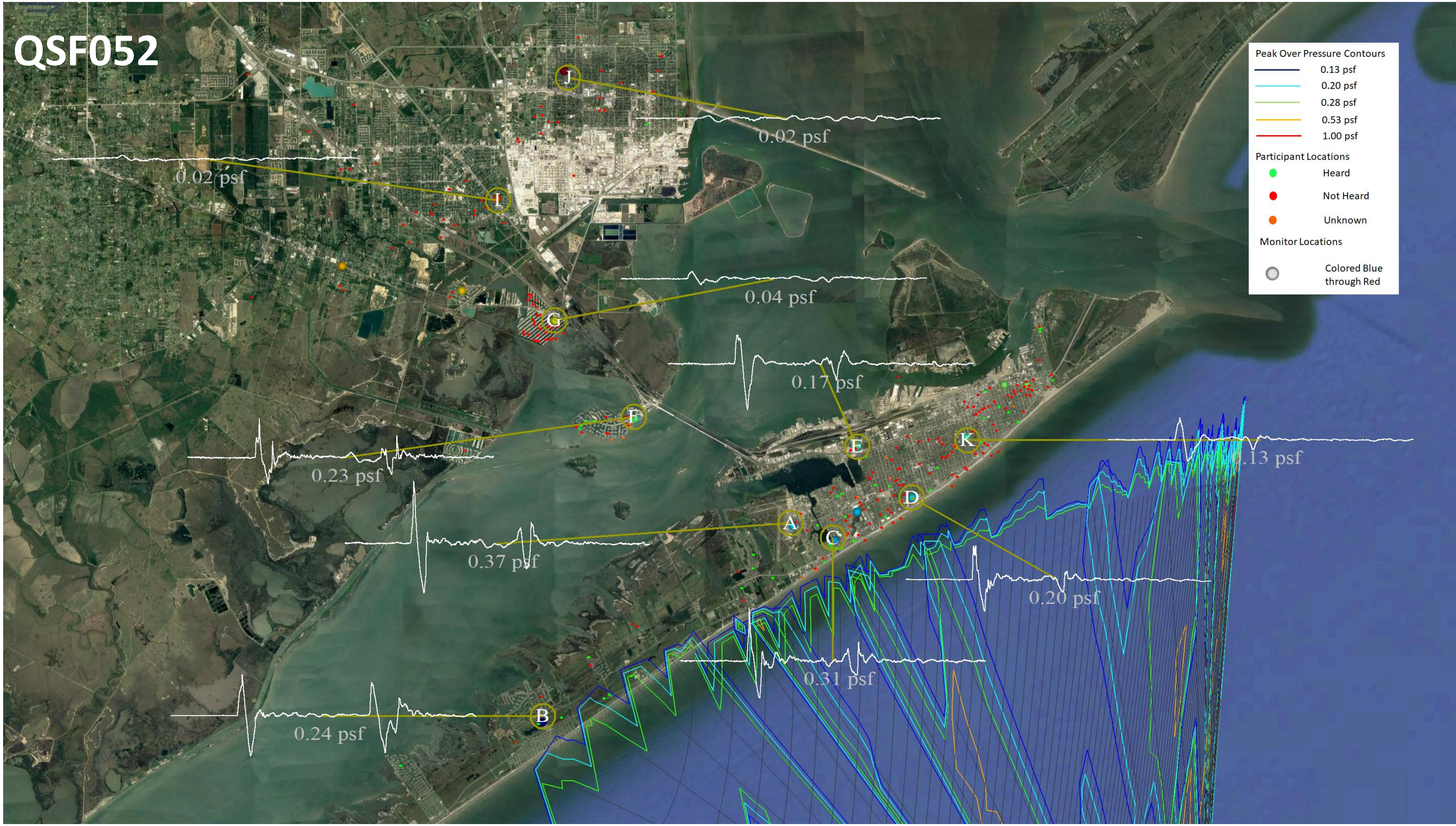

QSF048
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.01 psf
I
0.02 psf
H
0.02 psf
G
0.04 psf
0.16 psf
F
0.08 psf
E
K
0.15 psf
D
0.27 psf
A
0.26 psf
C
0.20 psf
B
0.17 psf


QSF049
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.01 psf
G
0.02 psf
0.14 psf
F
0.08 psf
E
K
0.15 psf
D
A
C
0.23 psf
0.20 psf
0.17 psf
B
0.17 psf


QSF050
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.01 psf
H
0.01 psf
G
0.02 psf
0.09 psf
F
0.09 psf
E
K
0.15 psf
D
A
C
0.10 psf
0.16 psf
0.13 psf
B
0.23 psf



QSF051
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
G
0.02 psf
0.17 psf
F
0.07 psf
E
K
0.15 psf
D
A
C
0.18 psf
0.25 psf
0.14 psf
B
0.19 psf



QSF052
Peak Over Pressure Contours
0.13 psf
0.20 psf
0.28 psf
0.53 psf
1.00 psf
Participant Locations
Heard
Not Heard
Unknown
Monitor Locations
Colored Blue through Red
J
0.02 psf
I
0.02 psf
G
0.04 psf
0.17 psf
F
0.23 psf
E
K
0.13 psf
D
A
C
0.37 psf
0.20 psf
0.31 psf
B
0.24 psf

R. Flight and False Reminder Records

The following pages provide Appendix R. This appendix file is provided separately from the main body of the report.

Flight and False Reminder Records

Below are all of the records for the flights and false reminders. For each flight pass and reminder, there is an associated field called "Tagging Approach", which refers to the method used to tag Single Event (SE) reports to that specific flight pass or false reminder. This tagging process is manual and can be subjective. Many of these decisions seemed clear when considering survey response patterns (large batches of surveys were coming in all time stamped similarly) against the flight and reminder schedule, whereas others were very difficult. The decision, for example, of whether to go one or two 15-minute intervals out from a flight/reminder to tag those responses to that flight/reminder was dependent on boom separation time. In turn, boom separation time was contingent upon flight operation conditions, which were highly sensitive to weather.

These "Tagging Approach" fields have values of the form BACKWARD_X_FORWARD_Y_ or FORWARD_Y_. The X and Y refer to the number of 15 minutes intervals either preceding or following the measured boom time for which we decided the respondents were offering reports. For example, Pass 2 of Flight 1 had a measured boom time of 9:25, and the tagging approach is FORWARD2. So any reports that came in saying they are responding to something at 9:30 or 9:45 on this day are labeled as F1P2 reports. As another example, Pass 1 of Flight 11 had a measured boom time of 12:00, and the tagging approach is FORWARD2. So any reports that came in saying they are responding to something at 12:00 or 12:15 on this day are labeled as F11P1 reports.

Regarding nomenclature, the following should be noted. Ground control at Scholes Airport would inform all field personnel via LMRS radio of the status of each flight: Take off, turn in, and commencement of the low boom dive maneuver. "Turn in" defines when the F-18 aircraft began the final turn toward the test community, signifying the start of the test point. "Mark" signified the start of the low boom dive maneuver.

Test Day 1 Monday 11/5/18

Flight Day 1

Flight/Pass: FLT001PASS001
Mark Time: 08:57
Meas. Boom Time: 09:?? @alpha noise monitor (Scholes Airport) **No boom heard.**
Reminder sent: 9:10
Tagging Approach: FORWARD2 (Using Mark Time here rather than Measured Time, so 9:00 and 9:15)

Flight/Pass: FLT001PASS002
Mark Time: 09:22
Meas. Boom Time: 09:25 @alpha noise monitor (Scholes Airport)
Reminder sent: 9:35
Tagging Approach: FORWARD2

Flight/Pass: FLT001PASS003
Aircraft: NASA 846
No data available due to networking issues.
Thump scheduled for: 9:50 with Reminder sent: at 10:00
Tagging Approach: FORWARD2

False Reminder 10:50
Tagging Approach: FORWARD2

Flight/Pass: FLT002PASS001
Mark Time: 13:18
Meas. Boom Time: 13:21 @alpha noise monitor (Scholes Airport)
Reminder to be sent 13:30 (1:30)
Not Sent
Tagging Approach: FORWARD2

Flight/Pass: FLT002PASS002
Mark Time: 13:47
Meas. Boom Time: 13:49 @alpha noise monitor (Scholes Airport)
Reminder to be sent 13:50 (1:50)
Not Sent
Tagging Approach: BACKWARD1FORWARD1 (13:45, 14:00), did not include 14:15, however could add 14:15 (which only had 14 responses)

False Reminder 14:30 (2:30)
False Reminder 14:35 (2:35)
Tagging Approach: BACKWARD1FORWARD2 (14:15, 14:30, 14:45)

Flight/Pass: FLT003PASS001
Mark Time: 15:05
Meas. Boom Time: 15:07 @alpha noise monitor (Scholes Airport)
Reminder to be sent 15:10 (3:10)
Reminder sent: 15:00
Tagging Approach: BACKWARD1FORWARD2 (15:00, 15:15, 15:30)

Flight/Pass: FLT003PASS002
Mark Time: 15:36
Meas. Boom Time: 15:37 @alpha noise monitor (Scholes Airport)
Reminder sent: 15:50 (3:50)

Tagging Approach: FORWARD2

False Reminder 4:18
Tagging Approach: BACKWARD1FORWARD1

Test Day 2 Tuesday 11/6/18

False Reminder 10:00
Tagging Approach: FORWARD2

Flight/Pass: FLT004PASS001
Mark Time: 10:57
Meas. Boom Time: 11:00 @alpha noise monitor (Scholes Airport)
Reminder sent: 11:10
Tagging Approach: FORWARD2

Flight/Pass: FLT004PASS002
Mark Time: 11:23
Meas. Boom Time: 11:25 @alpha noise monitor (Scholes Airport)
Reminder sent: 11:35
Tagging Approach: FORWARD2

Flight/Pass: FLT004PASS003
Mark Time: 11:47
Meas. Boom Time: 11:50 @alpha noise monitor (Scholes Airport)
Reminder to be sent: 12:00
Not sent
Tagging Approach: FORWARD2

False Reminder 1:00
Tagging Approach: FORWARD2

Flight/Pass: FLT005PASS001
Mark Time: 13:57
Meas. Boom Time: 14:00 @alpha noise monitor (Scholes Airport)
Reminder sent: 14:10 (2:10)
Not Sent
Tagging Approach: FORWARD2

Flight/Pass: FLT005PASS002
Mark Time: 14:22
Meas. Boom Time: 14:25 @alpha noise monitor (Scholes Airport)
Reminder sent: 14:35
Tagging Approach: FORWARD2

Flight/Pass: FLT005PASS003
Mark Time: 14:48
Meas. Boom Time: 14:51 @alpha noise monitor (Scholes Airport)
Reminder sent: 15:00
Tagging Approach: FORWARD1 (too close to false reminder. Usually want 15:15 here as well, but FR at 15:10)

False Reminder 15:10
Tagging Approach: FORWARD2
False Reminder 16:45
Tagging Approach: FORWARD2

Test Day 3 Wednesday 11/7/18

Flight/Pass: FLT006PASS001
Mark Time: 08:20
Meas. Boom Time: 08:22 @alpha noise monitor (Scholes Airport)
Reminder sent: 08:20
Tagging Approach: BACKWARD1FORWARD1

Flight/Pass: FLT006PASS002
Mark Time: 08:43
Meas. Boom Time: 08:46 @alpha noise monitor (Scholes Airport)
Reminder sent: 08:55
Tagging Approach: BACKWARD1FORWARD1

Flight/Pass: FLT006PASS003
Mark Time: 09:05
Meas. Boom Time: 09:07 @alpha noise monitor (Scholes Airport)
Reminder sent: 09:20
Tagging Approach: FORWARD2

False Reminder 10:20
Tagging Approach: BACKWARD1FORWARD1

Flight/Pass: FLT007PASS001

Mark Time: 11:58
Meas. Boom Time: 12:00 @alpha noise monitor (Scholes Airport)
Reminder sent: 12:10
Tagging Approach: FORWARD2

Flight/Pass: FLT007PASS002
No event. Flight called off due to weather.
Tagging Approach: NO EVENT

False Reminder **12:35**
Tagging Approach: BACKWARD1FORWARD1
False Reminder **13:50**
Tagging Approach: BACKWARD1FORWARD1

Test Day 4 Thursday 11/8/18

False Reminder **8:45**
Tagging Approach: FORWARD2

Flight/Pass: FLT008PASS001
Mark Time: 11:01
Meas. Boom Time: 11:03 @alpha noise monitor (Scholes Airport)
Reminder sent: 11:10
Tagging Approach: BACKWARD1FORWARD1

Flight/Pass: FLT008PASS002
Mark Time: 11:16
Meas. Boom Time: 11:18 @alpha noise monitor (Scholes Airport)
Reminder sent: 11:35
Tagging Approach: FORWARD2

Change from planned schedule. No pass 3 at 11:40.
False Reminder **11:50**
Tagging Approach: FORWARD2 (Not sure about 11:45. While only 10 minutes from the reminder, it is 30 minutes from the actual event, and only 5 minutes before the FR…could easily be FR responses)

Flight/Pass: FLT009PASS001
Mark Time: 12:56
Meas. Boom Time: 12:58 @alpha noise monitor (Scholes Airport)
Reminder sent: 13:10
Tagging Approach: FORWARD2

Flight/Pass: FLT009PASS002
Mark Time: 13:18
Meas. Boom Time: 13:20 @alpha noise monitor (Scholes Airport)
Reminder sent: 13:35
Tagging Approach: FORWARD2

False Reminder 13:50
Tagging Approach: FORWARD2
False Reminder 3:30
Tagging Approach: BACKWARD1FORWARD2 (15:15-15:45)

Test Day 5 Friday 11/9/18 RESPITE

False Reminder 9:20
Tagging Approach: BACKWARD1FORWARD1
False Reminder 11:30
Tagging Approach: FORWARD2
False Reminder 4:10
Tagging Approach: BACKWARD1FORWARD1

Test Day 6 Saturday 11/10/18

False Reminder 8:50
Tagging Approach: BACKWARD1FORWARD1

Flight/Pass: FLT010PASS001
Mark Time: 09:57
Meas. Boom Time: 09:59 @alpha noise monitor (Scholes Airport)
Reminder sent: 10:10
Tagging Approach: FORWARD2

Flight/Pass: FLT010PASS002
Mark Time: 10:32
Meas. Boom Time: 10:35 @alpha noise monitor (Scholes Airport)
Reminder sent: 10:45
Tagging Approach: BACKWARD1FORWARD1

False Reminder 11:30
Tagging Approach: FORWARD2

Flight 11

Flight/Pass: FLT011PASS001
Mark Time: 11:58
Meas. Boom Time: 12:00 @alpha noise monitor (Scholes Airport)
Reminder sent: 12:10
Tagging Approach: FORWARD2

Flight/Pass: FLT011PASS002
Mark Time: 12:24
Meas. Boom Time: 12:25 @alpha noise monitor (Scholes Airport)
Reminder sent: 12:35
Tagging Approach: FORWARD2

Flight/Pass: FLT011PASS003
Mark Time: 12:48
Meas. Boom Time: 12:50 @alpha noise monitor (Scholes Airport)
Reminder sent: 13:00
Tagging Approach: FORWARD2

Flight/Pass: FLT012PASS001
Mark Time: 15:58
Meas. Boom Time: 16:00 @alpha noise monitor (Scholes Airport)
Reminder sent:: 16:10
Tagging Approach: FORWARD2

Flight/Pass: FLT012PASS002
Mark Time: 16:27
Meas. Boom Time: 16:29 @alpha noise monitor (Scholes Airport)
Reminder sent:: 16:40
Tagging Approach: FORWARD2

Test Day 7 Sunday 11/11/18

False Reminder 9:20
Tagging Approach: BACKWARD1FORWARD1

Flight/Pass: FLT013PASS001
Mark Time: 11:18
Meas. Boom Time: 11:20 @alpha noise monitor (Scholes Airport)
Reminder sent: 11:20
Tagging Approach: BACKWARD1FORWARD1

Flight/Pass: FLT013PASS002
Mark Time: 11:38
Meas. Boom Time: 11:40 @alpha noise monitor (Scholes Airport)

Reminder sent: 11:45
Tagging Approach: FORWARD2

False reminder 12:30
Tagging Approach: FORWARD2

Flight/Pass: FLT014PASS001
Mark Time: 13:04
Meas. Boom Time: 13:06 @alpha noise monitor (Scholes Airport)
Reminder sent: 13:25
Tagging Approach: BACKWARD1FORWARD1 (20 minute late reminder)

Flight/Pass: FLT014PASS002
Mark Time: 13:33
Meas. Boom Time: 13:35 @alpha noise monitor (Scholes Airport)
Reminder sent: 13:45
Tagging Approach: BACKWARD1FORWARD2 (13:30-14:00)

Flight/Pass: FLT015PASS001
Mark Time: 14:58
Meas. Boom Time: 14:59 @alpha noise monitor (Scholes Airport)
Reminder sent: 15:10
Tagging Approach: FORWARD2

Flight/Pass: FLT015PASS002
Mark Time: 15:27
Meas. Boom Time: 15:29 @alpha noise monitor (Scholes Airport)
Reminder sent: 15:40
Tagging Approach: FORWARD2

Test Day 8 Monday 11/12/18 RESPITE Veteran's Day

False reminder 11:15
Tagging Approach: FORWARD2
False reminder 13:00
Tagging Approach: FORWARD2
False reminder 14:40
Tagging Approach: BACKWARD1FORWARD1
False reminder 15:10
Tagging Approach: BACKWARD1FORWARD1

Test Day 9 Tuesday 11/13/18

False Reminder **8:40**
Tagging Approach: BACKWARD1FORWARD1
False Reminder **10:10**
Tagging Approach: BACKWARD1FORWARD1

Flight/Pass: FLT016PASS001
Mark Time: 15:06
Meas. Boom Time: 15:08 @alpha noise monitor (Scholes Airport)
Reminder to be sent: 15:20
Not Sent
Tagging Approach: BACKWARD1FORWARD1

Flight/Pass: FLT016PASS002
Mark Time: 15:30
Meas. Boom Time: 15:32 @alpha noise monitor (Scholes Airport)
Reminder sent: 15:35
Tagging Approach: BACKWARD1FORWARD1

Flight/Pass: FLT016PASS003
Mark Time: 15:56
Meas. Boom Time: 15:58 @alpha noise monitor (Scholes Airport)
Reminder sent: 16:00
Tagging Approach: FORWARD2

False Reminder **16:25**
Tagging Approach: FORWARD1

Flight/Pass: FLT017PASS001
Mark Time: 16:37
Meas. Boom Time: 16:39 @alpha noise monitor (Scholes Airport)
Reminder sent: 16:50
Tagging Approach: FORWARD1

Flight/Pass: FLT017PASS002
Mark Time: 16:58
Meas. Boom Time: 16:59 @alpha noise monitor (Scholes Airport)
Reminder sent: 17:10
Tagging Approach: FORWARD1

*** From 16:25-16:59, we have one FR and two thumps. Very difficult to discern to which stimulus they are responding.

Test Day 10 Wednesday 11/14/18

Flight/Pass: FLT018PASS001
Mark Time: 08:58
Meas. Boom Time: 09:00 @alpha noise monitor (Scholes Airport)
Reminder sent:: 09:10
Tagging Approach: FORWARD2

Flight/Pass: FLT018PASS002
Mark Time: 09:24
Meas. Boom Time: 09:25 @alpha noise monitor (Scholes Airport)
Reminder sent:: 09:35
Tagging Approach: FORWARD1

Flight/Pass: FLT018PASS003
Mark Time: 09:43
Meas. Boom Time: 09:45 @alpha noise monitor (Scholes Airport)
Reminder sent:: 10:00
Tagging Approach: FORWARD2

False Reminder 11:15
Tagging Approach: FORWARD2
False Reminder 13:00
Tagging Approach: FORWARD2

Flight/Pass: FLT019PASS001
Mark Time: 14:02
Meas. Boom Time: 14:04 @alpha noise monitor (Scholes Airport)
Reminder sent: 14:10
Tagging Approach: BACKWARD1FORWARD1

Flight/Pass: FLT019PASS002
Mark Time: 14:28
Meas. Boom Time: 14:30 @alpha noise monitor (Scholes Airport)
Reminder sent:: 14:40
Tagging Approach: FORWARD2

Flight/Pass: FLT020PASS001
Mark Time: 14:58
Meas. Boom Time: 15:00 @alpha noise monitor (Scholes Airport)
Reminder sent:: 15:10
Tagging Approach: FORWARD2

Flight/Pass: FLT020PASS002

Mark Time: 15:22
Meas. Boom Time: 15:24 @alpha noise monitor (Scholes Airport)
Reminder sent:: 15:35
Tagging Approach: FORWARD2

Flight/Pass: FLT020PASS003
Mark Time: 15:47
Meas. Boom Time: 15:49 @alpha noise monitor (Scholes Airport)
Reminder sent:: 16:00
Tagging Approach: FORWARD2

Test Day 11 Thursday 11/15/18

Flight/Pass: FLT021PASS001
Mark Time: 08:57
Meas. Boom Time: 09:00 @alpha noise monitor (Scholes Airport)
Reminder sent:: 09:10
Tagging Approach: FORWARD2

Flight/Pass: FLT021PASS002
Mark Time: 09:22
Meas. Boom Time: 09:25 @alpha noise monitor (Scholes Airport)
Reminder sent:: 09:35
Tagging Approach: FORWARD2

Flight/Pass: FLT021PASS003
Mark Time: 09:48
Meas. Boom Time: 09:50 @alpha noise monitor (Scholes Airport)
Reminder sent:: 10:00
Tagging Approach: FORWARD2

False Reminder 10:40
Tagging Approach: BACKWARD1FORWARD1

Flight/Pass: FLT022PASS001
Mark Time: 10:57
Meas. Boom Time: 11:00 @alpha noise monitor (Scholes Airport)
Reminder sent:: 11:10
Tagging Approach: FORWARD2

Flight/Pass: FLT022PASS002
Mark Time: 11:27
Meas. Boom Time: 11:30 @alpha noise monitor (Scholes Airport)

Reminder sent:	11:40	
Tagging Approach:	FORWARD2	
False Reminder	12:10	(possibly after fly-by)
Tagging Approach:	BACKWARD1FORWARD1	

S. QSF18 Supplementary Statistics

The following pages provide Appendix S. This appendix file is provided separately from the main body of the report.

S. QSF18 Supplementary Statistics

Additional SE smoothed plots

Figure S-1 through Figure S-11 show the twice smoothed locally estimated scatterplot smoothing (LOESS) model fit for percentage Highly Annoyed (HA) for single events as a function of noise dose, including both the LOESS confidence bounds and the raw annoyance data calculated using the binning method described above in Section 6.3, for the remaining 11 metrics calculated for the noise. The one exception for the binning is with Max PSF, which cannot use a bin size of 4. There, a bin size of .05 is implemented in order to get a sufficient number of reports in the bins to generate meaningful data. The amount of smoothing done in SAS PROC LOESS (e.g. the smoothing parameter) for the metrics are listed in Table S-1. The percentage highly annoyed, number of highly annoyed, and number of data points are provided for each frequency bin for each of the single event metrics in Table S-2 through Table S-13.

Table S-1 Single event smoothing parameters for each metric

Metric	Smoothing Parameter
ASEL	0.1005502
BSEL	0.03588266
CSEL	0.1990915
DSEL	0.1388746
ESEL	0.0831298
FSEL	0.6242066
ISBAP	0.08075781
LLZd	0.06653047
LLZf	0.0404157
PL	0.1067625
PNL	0.09904068
MxPSF	0.1418409

Table S-2 ASEL data for binned single event %HA

Bin Midpoint [dB]	%HA	num.HA	N	metric_name
39.69	6.25	1	16	ASEL
43.69	0	0	219	ASEL
47.69	0.743494	4	538	ASEL
51.69	0.259067	3	1158	ASEL
55.69	0.415225	6	1445	ASEL
59.69	0.987433	11	1114	ASEL
63.69	2.54491	17	668	ASEL
67.69	3.155819	16	507	ASEL
71.69	2.061856	2	97	ASEL

Table S-3 BSEL data for binned single event %HA

Bin Midpoint	%HA	num.HA	N	metric_name
53.49	0	0	117	BSEL
57.49	0	0	151	BSEL
61.49	0.630915	4	634	BSEL
65.49	0.284495	4	1406	BSEL
69.49	0.394477	4	1014	BSEL
73.49	0.863724	9	1042	BSEL
77.49	2.23152	16	717	BSEL
81.49	3.184713	20	628	BSEL
85.49	0.680272	1	147	BSEL

Table S-4 CSEL data for binned single event %HA

Bin Midpoint	%HA	num.HA	N	metric_name
60.89	0	0	51	CSEL
64.89	0.558659	1	179	CSEL
68.89	0.340136	1	294	CSEL
72.89	0	0	361	CSEL
76.89	0.318471	3	942	CSEL
80.89	0.397456	5	1258	CSEL
84.89	0.88968	10	1124	CSEL
88.89	1.576577	14	888	CSEL
92.89	3.010471	23	764	CSEL
96.89	4.385965	5	114	CSEL

Table S-5 DSEL data for binned single event %HA

Bin Midpoint	%HA	num.HA	N	metric_name
54.39	0	0	47	DSEL
58.39	0.597015	2	335	DSEL
62.39	0.231481	1	432	DSEL
66.39	0.459137	5	1089	DSEL
70.39	0.278552	4	1436	DSEL
74.39	0.821168	9	1096	DSEL
78.39	1.945525	15	771	DSEL
82.39	3.276353	23	702	DSEL
86.39	4.109589	3	73	DSEL

Table S-6 ESEL data for binned single event %HA

Bin Midpoint	%HA	num.HA	N	metric_name
48.39	0	0	31	ESEL
52.39	0	0	171	ESEL
56.39	0.530973	3	565	ESEL
60.39	0.23678	3	1267	ESEL
64.39	0.347222	4	1152	ESEL
68.39	1.032864	11	1065	ESEL
72.39	1.743462	14	803	ESEL
76.39	3.832117	21	548	ESEL
80.39	1.176471	3	255	ESEL

Table S-7 FSEL data for binned single event %HA

Bin Midpoint	%HA	num.HA	N	metric_name
71.39	0	0	18	FSEL
75.39	0	0	38	FSEL
79.39	0	0	90	FSEL
83.39	0.729927	2	274	FSEL
87.39	0.240964	1	415	FSEL
91.39	0.163399	1	612	FSEL
95.39	0.567537	5	881	FSEL
99.39	0.507614	8	1576	FSEL
103.39	1.245136	16	1285	FSEL
107.39	3.680203	29	788	FSEL

Table S-8 ISBAP data for binned single event %HA

Bin Midpoint	%HA	num.HA	N	metric_name
67.69	0	0	60	ISBAP
71.69	0	0	304	ISBAP
75.69	0.546448	4	732	ISBAP
79.69	0.321543	5	1555	ISBAP
83.69	0.553797	7	1264	ISBAP
87.69	1.28866	10	776	ISBAP
91.69	2.377807	18	757	ISBAP
95.69	3.598972	14	389	ISBAP
99.69	5.405405	2	37	ISBAP

Table S-9 LLZd data for binned single event %HA

Bin Midpoint	%HA	num.HA	N	metric_name
71.89	0	0	7	LLZd
75.89	0.803213	2	249	LLZd
79.89	0.441014	4	907	LLZd
83.89	0.205903	3	1457	LLZd
87.89	0.70922	10	1410	LLZd
91.89	1.792115	20	1116	LLZd
95.89	3.466205	20	577	LLZd
99.89	2	1	50	LLZd

Table S-10 LLZf data for binned single event %HA

Bin Midpoint	%HA	num.HA	N	metric_name
71.29	0	0	4	LLZf
75.29	1.058201	2	189	LLZf
79.29	0.504032	5	992	LLZf
83.29	0.075988	1	1316	LLZf
87.29	0.765484	11	1437	LLZf
91.29	1.483421	17	1146	LLZf
95.29	3.5	21	600	LLZf
99.29	3.409091	3	88	LLZf

Table S-11 PL data for binned single event %HA

Bin Midpoint	%HA	num.HA	N	metric_name
55.69	6.666667	1	15	PL
59.69	0	0	145	PL
63.69	0.896861	4	446	PL
67.69	0.250417	3	1198	PL
71.69	0.387847	6	1547	PL
75.69	1.030043	12	1165	PL
79.69	2.339181	16	684	PL
83.69	3.556485	17	478	PL
87.69	1.086957	1	92	PL

Table S-12 PNL data for binned single event %HA

Bin Midpoint	%HA	num.HA	N	metric_name
61.89	0	0	10	PNL
65.89	0.925926	1	108	PNL
69.89	0.287356	1	348	PNL
73.89	0.530786	5	942	PNL
77.89	0.149254	2	1340	PNL
81.89	0.603622	6	994	PNL
85.89	1.301518	12	922	PNL
89.89	2.773723	19	685	PNL
93.89	3.385417	13	384	PNL
97.89	2.5	1	40	PNL

Table S-13 MxPSF data for binned single event %HA

Bin Midpoint	%HA	num.HA	N	metric_name
0	0.412371	2	485	MxPSF
0.05	0.175131	2	1142	MxPSF
0.1	0.513347	5	974	MxPSF
0.15	0.419111	5	1193	MxPSF
0.2	0.961538	6	624	MxPSF
0.25	1.084599	5	461	MxPSF
0.3	1.70068	5	294	MxPSF
0.35	4.504505	10	222	MxPSF
0.4	2.857143	6	210	MxPSF
0.45	4.56621	10	219	MxPSF
0.5	1.086957	1	92	MxPSF
0.55	4.545455	2	44	MxPSF
0.6	23.076923	3	13	MxPSF
0.65	8.333333	1	12	MxPSF

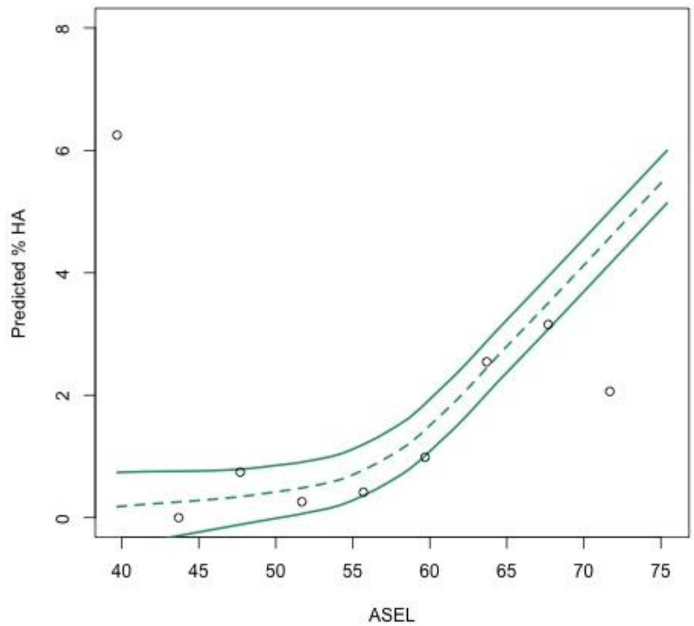


Figure S-1 ASEL dose response curve

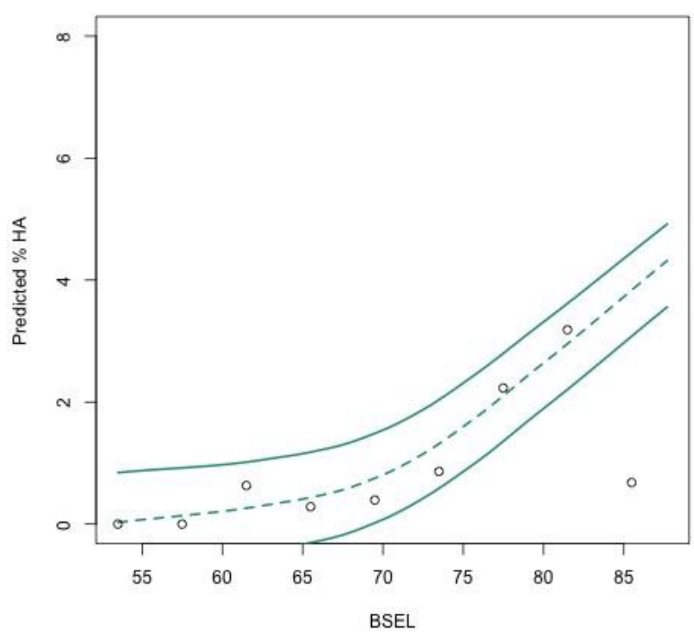


Figure S-2 BSEL dose response curve

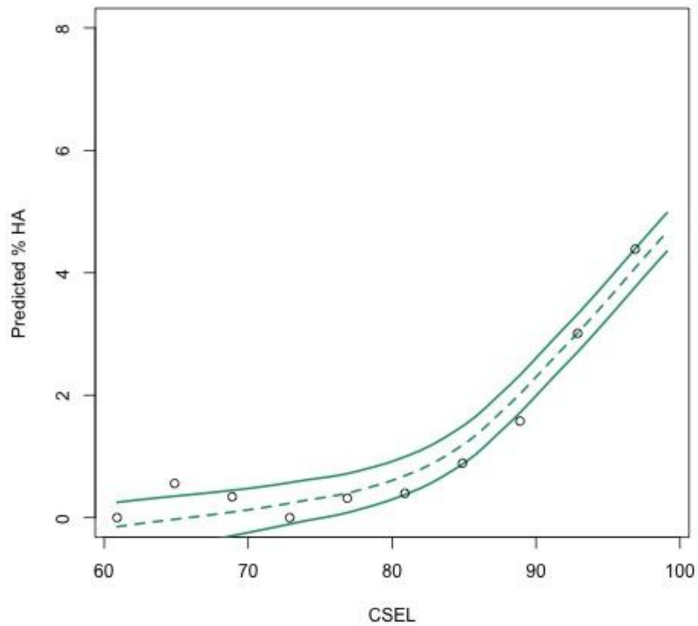


Figure S-3 CSEL dose response curve

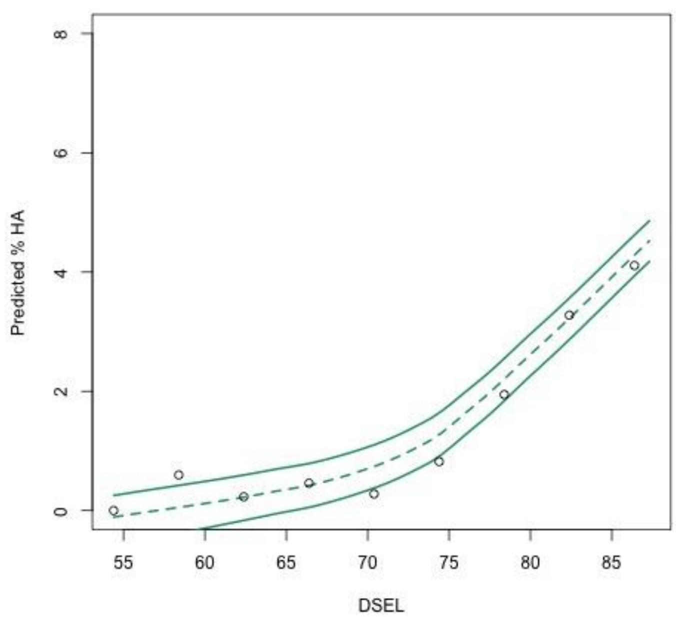


Figure S-4 DSEL dose response curve

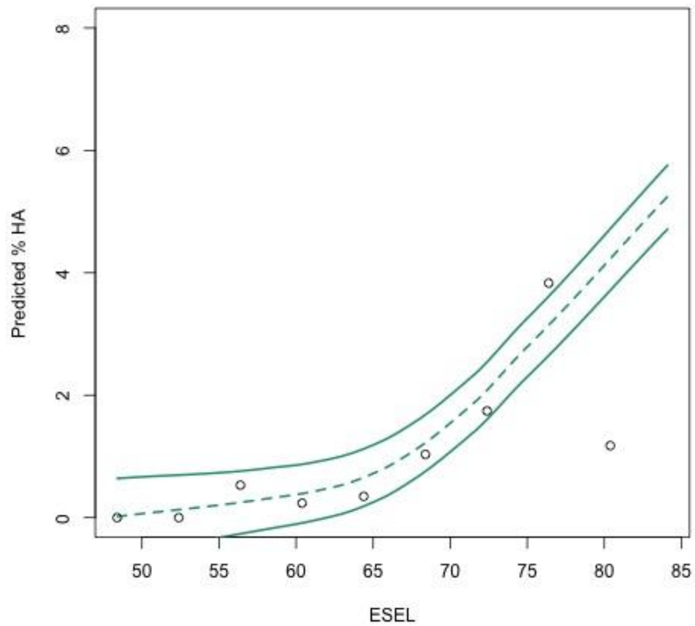


Figure S-5 ESEL dose response curve

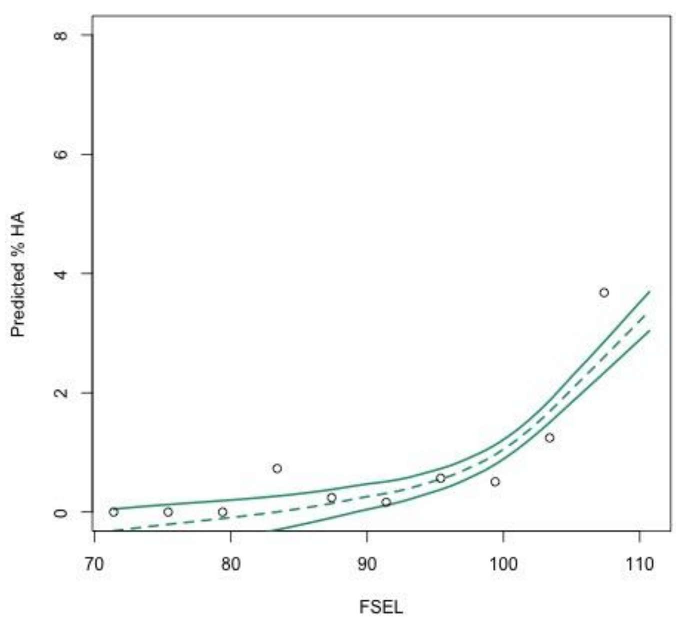


Figure S-6 FSEL dose response curve

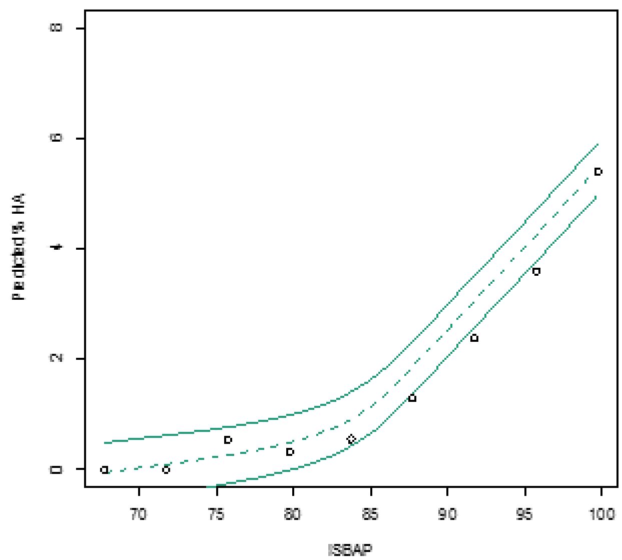


Figure S-7 ISBAP dose response curve

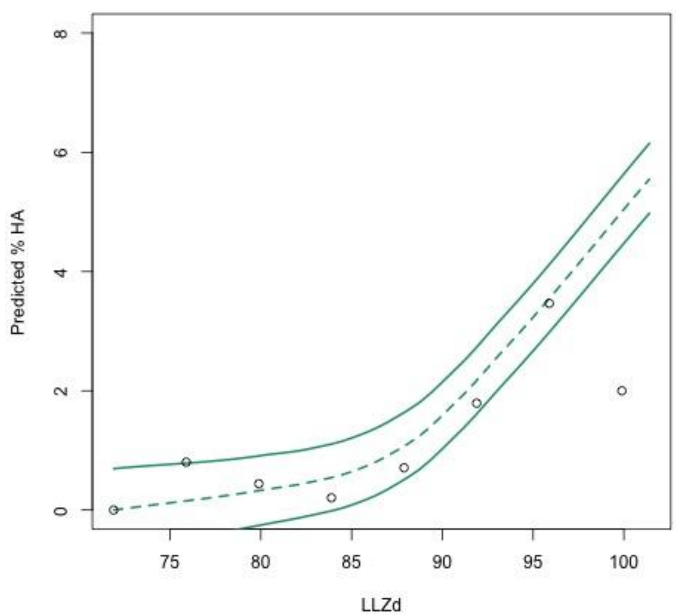


Figure S-8 LLZd dose response curve

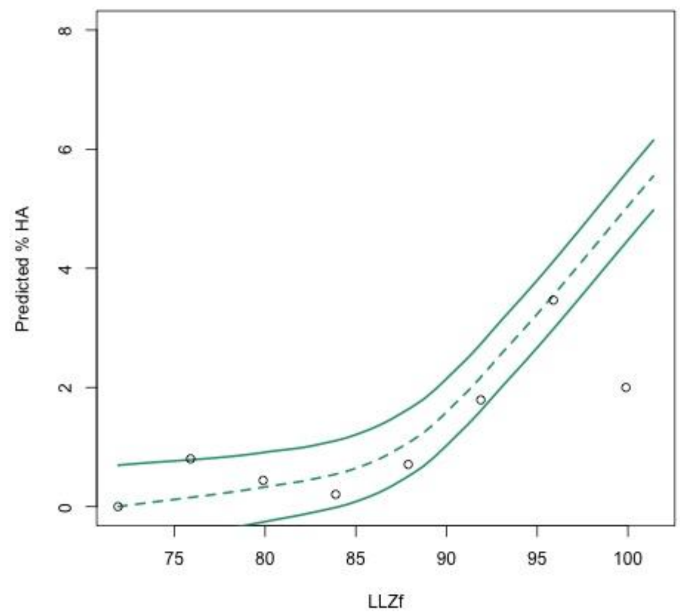


Figure S-9 LLZf dose response curve

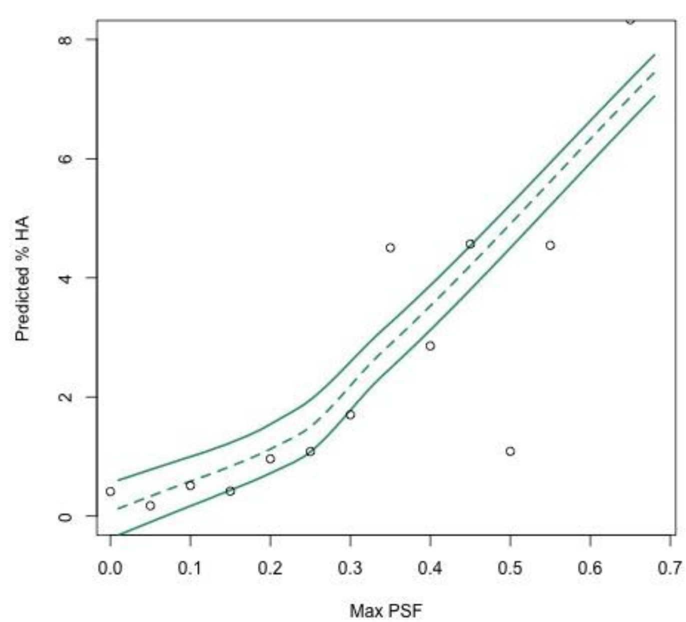


Figure S-10 Max PSF dose response curve (one observation is off the chart scale: In the 0.575 to 0.625 Max PSF bin, the corresponding percentage is 23.1%)

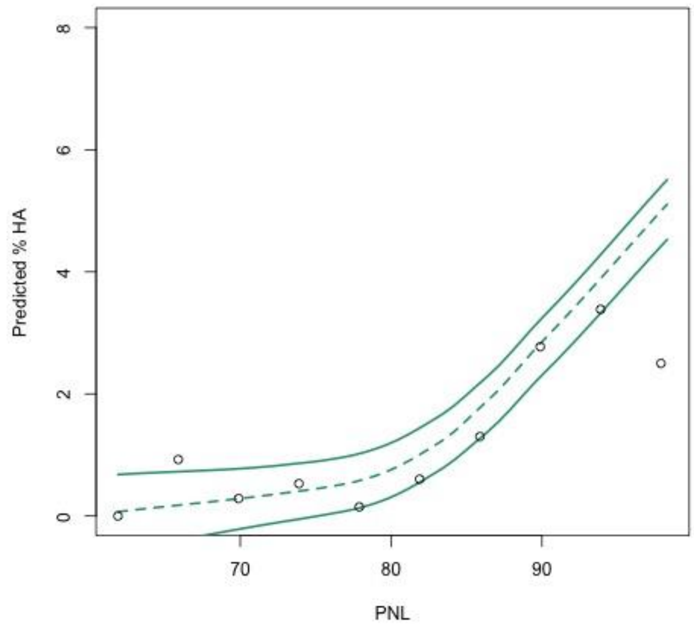


Figure S-11 PNL dose respose curve

Additional DS smoothed plots

Figure S-12 through Figure S-21 show the smoothed LOESS model fit for percentage HA for daily summaries as a function of noise dose, including both the LOESS confidence bounds and the raw annoyance data calculated using the binning method described above in Section 6.3, for the remaining 10 metrics calculated for the noise (N.B. Max PSF is not used for daily summary noise dose). The amount of smoothing done in SAS PROC LOESS (e.g. the smoothing parameter) for the metrics are listed in Table S-14. The percentage highly annoyed, number of highly annoyed, and number of data points are provided for each frequency bin for each of the daily summary metrics in Table S-15 through Table S-25.

Table S-14 Daily summary smoothing parameters for each metric

Metric	Smoothing Parameter
DNL	1
BDNL	1
CDNL	0.998784
DDNL	0. 998784
EDNL	1
FDNL	0.994893
DailyISBAP	1
DailyLLZd	0.277886
DailyLLZf	0.2973697
PLDN	1
DailyPNL	1

Table S-15 DNL data for binned daily summary %HA

Bin Midpoint	%HA	num.HA	N	metric_name
0.19	0	0	22	DNL
4.19	0	0	183	DNL
8.19	0.332226	1	301	DNL
12.19	0.802139	3	374	DNL
16.19	0.879121	4	455	DNL
20.19	1.366743	6	439	DNL
24.19	1.158301	3	259	DNL

Table S-16 BDNL data for binned daily summary %HA

Bin Midpoint	%HA	num.HA	N	metric_name
7.19	0	0	2	BDNL
11.19	0	0	27	BDNL
15.19	0	0	88	BDNL
19.19	0	0	230	BDNL
23.19	0.334448	1	299	BDNL
27.19	0.554017	2	361	BDNL
31.19	1.012658	4	395	BDNL
35.19	1.308411	7	535	BDNL
39.19	1.041667	2	192	BDNL

Table S-17 CDNL data for binned daily summary %HA

Bin Midpoint	%HA	num.HA	N	metric_name
17.89	0	0	1	CDNL
21.89	0	0	47	CDNL
25.89	0	0	44	CDNL
29.89	0	0	199	CDNL
33.89	0.429185	1	233	CDNL
37.89	0.318471	1	314	CDNL
41.89	0.21322	1	469	CDNL
45.89	1.751313	10	571	CDNL
49.89	1.632653	4	245	CDNL

Table S-18 DDNL data for binned daily summary %HA

Bin Midpoint	%HA	num.HA	N	metric_name
8.69	0	0	1	DDNL
12.69	0	0	4	DDNL
16.69	0	0	74	DDNL
20.69	0	0	248	DDNL
24.69	0.369004	1	271	DDNL
28.69	0.246914	1	405	DDNL
32.69	1.263158	6	475	DDNL
36.69	1.337793	8	598	DDNL
40.69	0	0	53	DDNL

Table S-19 EDNL data for binned daily summary %HA

Bin Midpoint	%HA	num.HA	N	metric_name
2.39	0	0	1	EDNL
6.39	0	0	35	EDNL
10.39	0	0	77	EDNL
14.39	0	0	208	EDNL
18.39	0.303951	1	329	EDNL
22.39	0.815217	3	368	EDNL
26.39	0.519481	2	385	EDNL
30.39	1.639344	8	488	EDNL
34.39	1.327434	3	226	EDNL

Table S-20 FDNL data for binned daily summary %HA

Bin Midpoint	%HA	num.HA	N	metric_name
33.19	0	0	45	FDNL
37.19	0	0	5	FDNL
41.19	0	0	11	FDNL
45.19	0	0	51	FDNL
49.19	0	0	221	FDNL
53.19	0.265957	1	376	FDNL
57.19	0.664894	5	752	FDNL
61.19	1.6	10	625	FDNL
65.19	0	0	43	FDNL

Table S-21 DailyISBAP data for binned daily summary %HA

Bin Midpoint	%HA	num.HA	N	metric_name
22.39	0	0	2	DailyISBAP
26.39	0	0	67	DailyISBAP
30.39	0	0	150	DailyISBAP
34.39	0	0	316	DailyISBAP
38.39	0.522193	2	383	DailyISBAP
42.39	0.246914	1	405	DailyISBAP
46.39	1.801802	10	555	DailyISBAP
50.39	1.195219	3	251	DailyISBAP

Table S-22 DailyLLZd data for binned daily summary %HA

Bin Midpoint	%HA	num.HA	N	metric_name
26.39	0	0	49	DailyLLZd
30.39	0	0	49	DailyLLZd
34.39	0	0	175	DailyLLZd
38.39	0.346021	1	289	DailyLLZd
42.39	0.433839	2	461	DailyLLZd
46.39	1.174168	6	511	DailyLLZd
50.39	1.282051	7	546	DailyLLZd
54.39	0	0	46	DailyLLZd

Table S-23 DailyLLZf data for binned daily summary %HA

Bin Midpoint	%HA	num.HA	N	metric_name
25.99	0	0	49	DailyLLZf
29.99	0	0	48	DailyLLZf
33.99	0	0	180	DailyLLZf
37.99	0	0	279	DailyLLZf
41.99	0.663717	3	452	DailyLLZf
45.99	1.174168	6	511	DailyLLZf
49.99	1.247772	7	561	DailyLLZf
53.99	0	0	46	DailyLLZf

Table S-24 PLDN data for binned daily summary %HA

Bin Midpoint	%HA	num.HA	N	metric_name
7.29	0	0	3	PLDN
11.29	0	0	39	PLDN
15.29	0	0	44	PLDN
19.29	0	0	141	PLDN
23.29	0	0	310	PLDN
27.29	0.765306	3	392	PLDN
31.29	0.478469	2	418	PLDN
35.29	2.107728	9	427	PLDN
39.29	0.877193	3	342	PLDN

Table S-25 DailyPNL data for binned daily summary %HA

Bin Midpoint	%HA	num.HA	N	metric_name
19.19	0	0	54	DailyPNL
23.19	0	0	44	DailyPNL
27.19	0	0	158	DailyPNL
31.19	0	0	252	DailyPNL
35.19	0.37037	1	270	DailyPNL
39.19	0.540541	2	370	DailyPNL
43.19	1.434426	7	488	DailyPNL
47.19	1.339286	6	448	DailyPNL

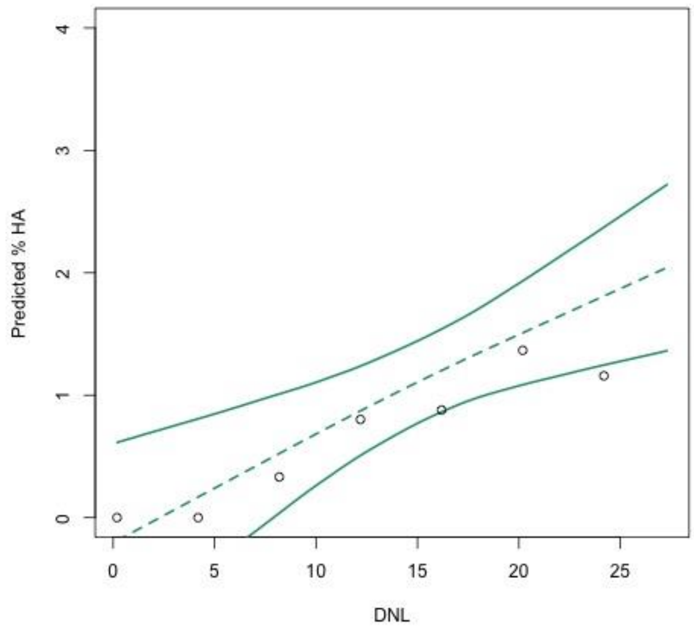


Figure S-12 DNL dose response curve

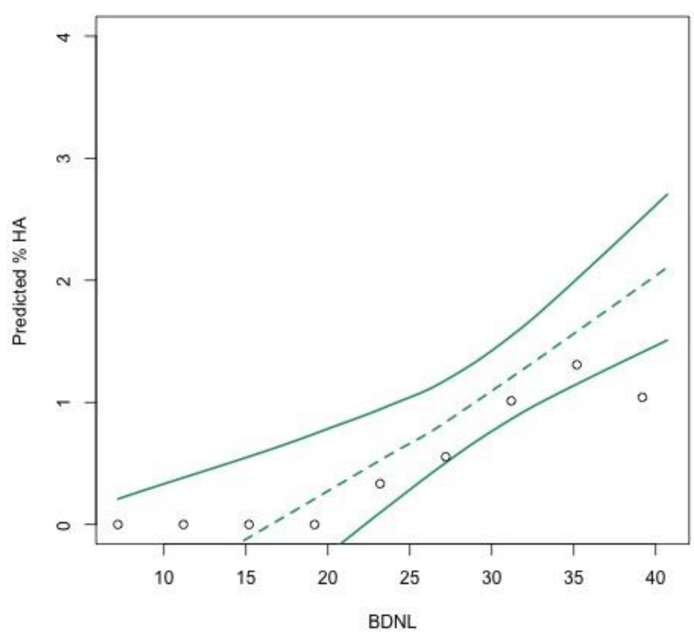


Figure S-13 BDNL dose response curve

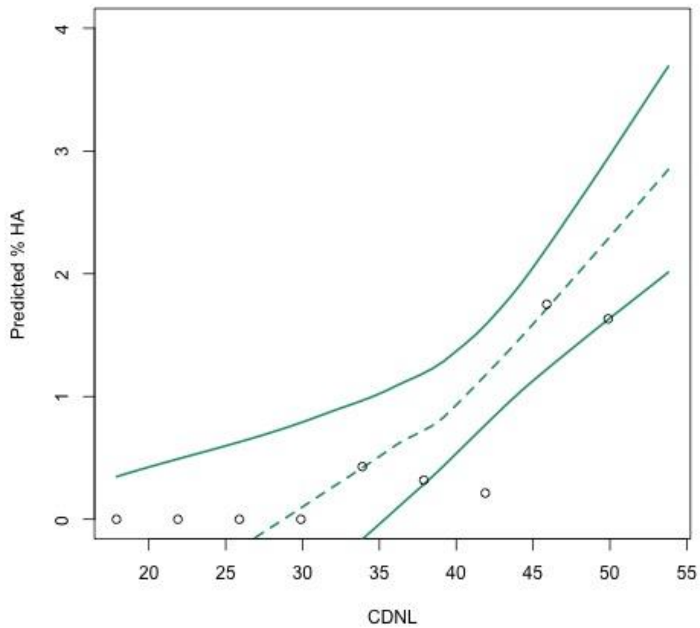


Figure S-14 CDNL dose response curve

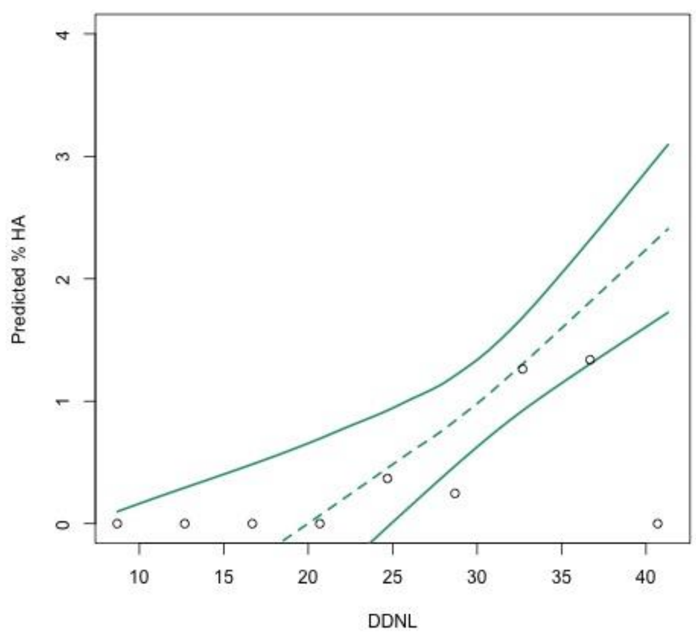


Figure S-15 DDNL dose response curve

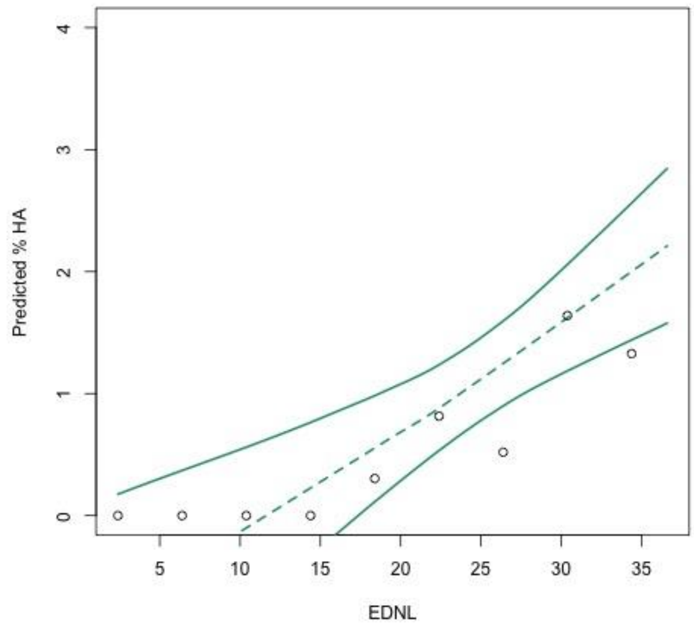


Figure S-16 EDNL dose response curve

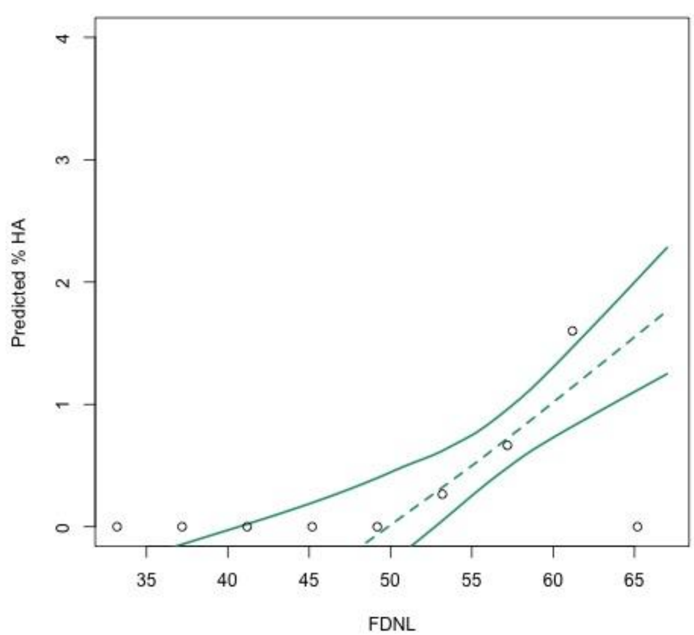


Figure S-17 FDNL dose response curve

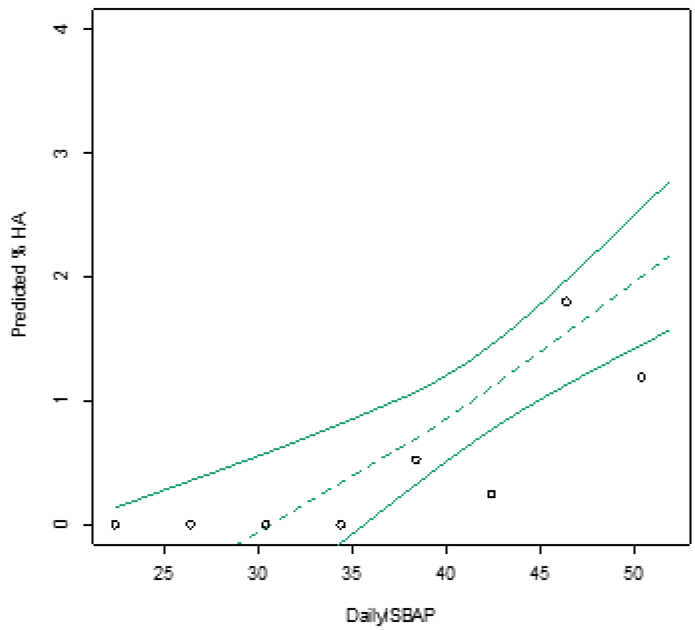


Figure S-18 Daily ISBAP dose response curve

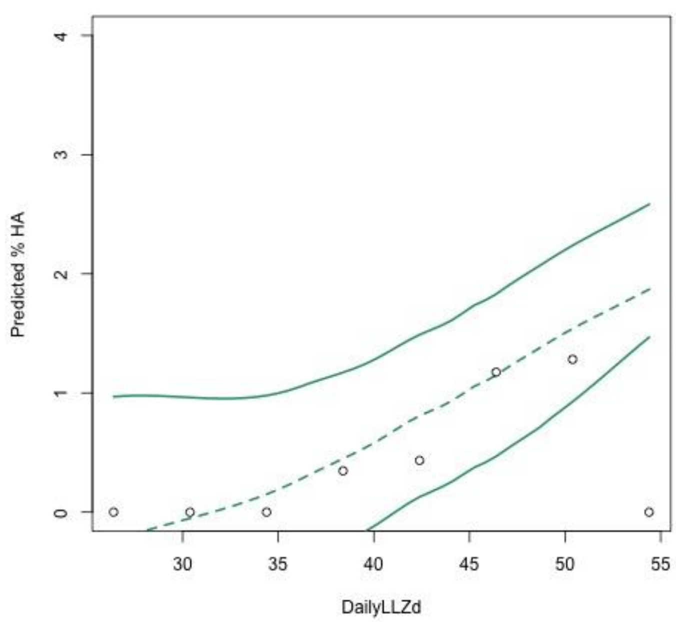


Figure S-19 Daily LLZd dose response curve

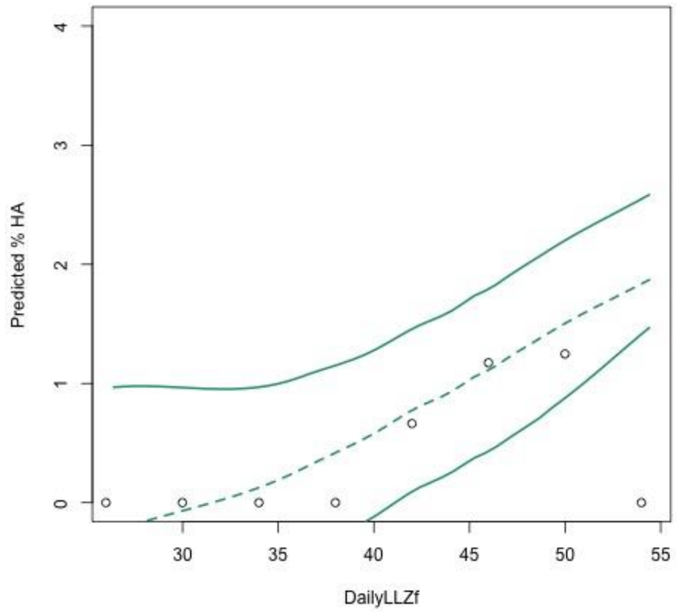


Figure S-20 Daily LLZf dose response curve

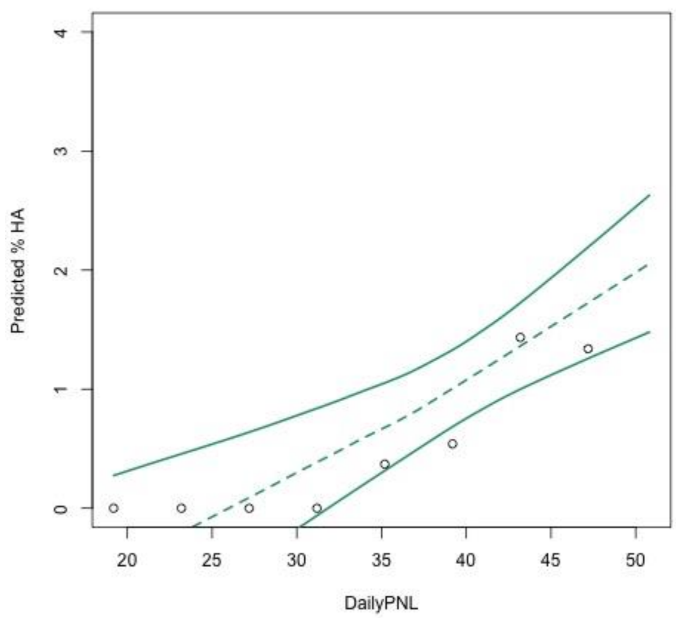


Figure S-21 Daily PNL dose response curve

T. QSF18 Noise Dose Comparison

The following pages provide Appendix T .This appendix file is provided separately from the main body of the report.

T. QSF18 Noise Dose Comparison

Summary tables have been prepared which show the designed and actual thump levels at each sensor. Summaries for PL and max PSF have been prepared. For readability, the tables are further broken down between sensors on Galveston Island (A, B, C, D, E, K), and sensors off Galveston Island (F, G, H, I, J). Note that the design levels are specifically for sensor Alpha, bearing that in mind the others can be compared as well. For the determination of actual dose (Q, L, M, and H as defined in the tables), the median of the Galveston Island sensors are used. Table T-1 and Table T-2 provide the PL summaries for sensors on and off Galveston Island, respectively. Table T-3 and Table T-4 provide the max PSF summaries for sensors on and off Galveston Island, respectively.

Table T-1 Target thump levels compared to measurements – PL at sensors on Galveston Island

Date	Thump #	QSF18 Flight	Pass	Design (Alpha)			Measured (Galveston Island)									Flown to Level
				Level [1]	Target PSF (max)	Target PLdB (max)	Actual Level [1] (based on median)	Measured PLdB (average)	Measured PLdB (median)	Alpha	Bravo	Charlie	Delta	Echo	Kilo	
11/5/2018	1	1	1	L	0.20	79.7	[2]			-	81.5	-	-	-	-	Q
11/5/2018	2	1	2	Q	0.13	73.7	Q	73.4	72.8	72	73	72.8	78.7	71.4	73	L
11/5/2018	3	1	3	Q	0.13	73.7	L	78.7	78.0	72.4	76.2	77.9	78.5	78.1	89	L
11/5/2018	4	2	1	L	0.20	79.7	Q	70.4	71.5	67.8	71.5	66.1	72.8	-	74	L
11/5/2018	5	2	2	Q	0.13	73.7	L	75.7	74.2	74.2	73.7	70.3	78.2	74.2	84	L
11/5/2018	6	3	1	L	0.20	79.7	Q	71.9	70.9	65.8	84.1	70.3	66.4	73.1	72	L
11/5/2018	7	3	2	Q	0.13	73.7	Q	71.3	70.9	70.2	76.8	67.6	67.9	73.7	72	L
11/6/2018	8	4	1	Q	0.13	73.7	Q	68.7	68.5	66.5	69.1	67.9	65.9	72.4	70	U
11/6/2018	9	4	2	Q	0.13	73.7	Q	72.6	71.5	71	82.1	73.9	69.3	71.9	67	Q
11/6/2018	10	4	3	Q	0.13	73.7	Q	68.3	67.7	65.4	72.7	65.2	68.3	71.2	67	Q
11/6/2018	11	5	1	Q	0.13	73.7	Q	66.4	67.5	67.4	63.2	63.9	67.5	68	68	Q
11/6/2018	12	5	2	Q	0.13	73.7	Q	65.2	65.0	61	64.6	62.8	65.4	65.8	72	Q
11/6/2018	13	5	3	Q	0.13	73.7	Q	69.5	70.1	74.8	72.8	73.4	64.2	67.3	64	L
11/7/2018	14	6	1	L	0.20	79.7	L	74.7	74.5	74.2	76.9	70.2	74.7	73.8	78	L
11/7/2018	15	6	2	L	0.20	79.7	Q	67.0	66.9	65.4	69.1	63.5	68.4	71.4	64	L

Date	Thump #	QSF18 Flight	Pass	Design (Alpha)			Measured (Galveston Island)									Flown to Level
				Level [1]	Target PSF (max)	Target PLdB (max)	Actual Level [1] (based on median)	Measured PLdB (average)	Measured PLdB (median)	Alpha	Bravo	Charlie	Delta	Echo	Kilo	
11/7/2018	16	6	3	L	0.20	79.7	L	77.3	76.7	75.1	73.4	75.1	82.4	78.3	79	M
11/7/2018	17	7	1	L	0.20	79.7	L	75.4	74.3	73	84.8	72.2	76.2	75.5	71	L
11/8/2019	18	8	1	M	0.28	84.0	Q	70.0	69.9	72.5	70	64.5	69.1	69.7	74	M
11/8/2019	19	8	2	L	0.20	79.7	L	78.0	78.6	72.9	72.2	80.2	81.5	76.9	84	H
11/8/2019	20	9	1	L	0.20	79.7	L	74.9	75.9	72.1	76.5	67.6	81.5	75.7	76	M
11/8/2019	21	9	2	M	0.28	84.0	H	84.4	84.9	83.7	77.5	83.2	89.2	86.1	87	H
11/10/2018	22	10	1	M	0.28	84.0	Q	71.4	71.8	72.2	72.5	71.4	67.4	75	70	M
11/10/2018	23	10	2	L	0.20	79.7	Q	72.4	72.2	75.1	69.9	67.6	77.7	74.4	70	M
11/10/2018	24	11	1	L	0.20	79.7	Q	70.3	71.2	71.8	71.2	68	-	67.5	73	M
11/10/2018	25	11	2	M	0.28	84.0	Q	71.4	71.8	75.7	73.3	73.8	65.5	69.8	70	MH
11/10/2018	26	11	3	M	0.28	84.0	M	83.9	83.4	81.3	83.8	89.7	84.5	82.9	81	H
11/10/2018	27	12	1	M	0.28	84.0	H	82.8	84.8	76.1	84.9	85.1	86.9	79.2	85	H
11/10/2018	28	12	2	M	0.28	84.0	M	80.3	80.9	79.9	76.2	77	82.9	83.9	82	MH
11/11/2018	29	13	1	L	0.20	79.7	Q	61.3	61.3	-	-	59.9	-	-	63	L
11/11/2018	30	13	2	M	0.28	84.0	L	75.9	75.6	73.5	80.8	77.6	79.3	72	72	MH
11/11/2018	31	14	1	M	0.28	84.0	L	79.8	79.3	71.6	77.2	77.3	81.3	85.8	85	MH
11/11/2018	32	14	2	L	0.20	79.7	Q	70.5	69.9	73.5	70.3	65	77.3	69.5	67	MH
11/11/2018	33	15	1	M	0.28	84.0	L	77.5	78.5	82.5	69.7	82.4	77.2	73.2	80	MH
11/11/2018	34	15	2	M	0.28	84.0	Q	70.8	69.1	68	-	69	72.7	69.1	75	MH
11/13/2018	35	16	1	M	0.28	84.0	L	76.6	75.4	74.9	-	75.4	73.4	82.6	77	M
11/13/2018	36	16	2	H	0.53	93.3	M	81.6	83.0	77.5	85.9	84.7	84.8	75.4	81	H
11/13/2018	37	16	3	H	0.53	93.3	L	79.4	78.4	85	76.7	76.7	75.9	82.1	80	H
11/13/2018	38	17	1	M	0.28	84.0	Q	68.5	68.4	70.2	65.6	66.6	66.5	71.5	71	M
11/13/2018	39	17	2	H	0.53	93.3	Q	73.0	73.7	67.9	73.7	74.8	71.9	-	77	MH

Date	Thump #	QSF18 Flight	Pass	Design (Alpha)			Measured (Galveston Island)									Flown to Level
				Level [1]	Target PSF (max)	Target PLdB (max)	Actual Level [1] (based on median)	Measured PLdB (average)	Measured PLdB (median)	Alpha	Bravo	Charlie	Delta	Echo	Kilo	
11/14/2018	40	18	1	M	0.28	84.0	L	73.2	75.6	75.6	80.3	78.6	64.9	66.5	-	M
11/14/2018	41	18	2	L	0.20	79.7	L	75.2	75.7	75.7	76.6	72.1	70.8	81	-	M
11/14/2018	42	18	3	M	0.28	84.0	L	79.6	78.7	81	81.6	76.4	87.9	74.7	76	MH
11/14/2018	43	19	1	L	0.20	79.7	Q	71.5	70.5	71.9	62.7	88.6	61.2	69.1	76	L
11/14/2018	44	19	2	L	0.20	79.7	Q	64.3	64.1	72	58.9	66.4	58.5	68.3	62	L
11/14/2018	45	20	1	L	0.20	79.7	Q	61.0	61.2	61.7	65.8	58.2	58	61.2	-	L
11/14/2018	46	20	2	L	0.20	79.7	Q	68.1	66.2	65.3	76.3	63.5	-	67.1	-	M
11/14/2018	47	20	3	L	0.20	79.7	Q	71.6	68.5	68.5	85.5	60.8	-	-	-	M
11/15/2018	48	21	1	L	0.20	79.7	Q	67.2	67.7	67.6	63.1	69.7	70.5	67.8	64	L
11/15/2018	49	21	2	L	0.20	79.7	Q	66.5	66.1	66.6	72.5	64.2	66.5	65.7	63	L
11/15/2018	50	21	3	L	0.20	79.7	Q	67.8	66.5	69.2	64.9	74.9	67.1	64.9	66	L
11/15/2018	51	22	1	L	0.20	79.7	Q	67.2	65.9	65.1	66.5	65.3	72.8	69.4	64	L
11/15/2018	52	22	2	L	0.20	79.7	Q	71.6	72.6	74.9	73.3	78.2	69.4	71.8	62	M

Note 1 - Level: Q < =73.7, 73.7<L<=79.7, 79.7<M<=84.0, 84.0<H]

Note 2 - Flight 1 Pass 1 thump only detected at Bravo, not included in analysis

Table T-2 Target thump levels compared to measurements – PL at sensors other than on Galveston Island

Date	Thump #	QSF18 Flight	Pass	Design (Alpha)			Measured (other)								Flown to Level
				Level [1]	Target PSF (max)	Target PLdB (max)	Measured PLdB (average)	Measured PLdB (median)	Foxtrot	Golf	Hotel	India	Juliet	
11/5/2018	1	1	1	L	0.20	79.7	[2]		-	-	-	-	-	Q
11/5/2018	2	1	2	Q	0.13	73.7	68.2	70.0	70.2	71	63.9	65.7	70	L
11/5/2018	3	1	3	Q	0.13	73.7	70.2	70.4	70.4	67	72.8	-	-	L
11/5/2018	4	2	1	L	0.20	79.7	66.8	65.9	70.6	66	64	-	-	L
11/5/2018	5	2	2	Q	0.13	73.7	67.7	68.3	70	70	64	66.6	-	L
11/5/2018	6	3	1	L	0.20	79.7	69.0	69.0	69	-	-	-	-	L
11/5/2018	7	3	2	Q	0.13	73.7	64.9	64.9	64.9	-	-	-	-	L
11/6/2018	8	4	1	Q	0.13	73.7	62.4	63.6	67.4	64	56.1	58.3	66.4	U
11/6/2018	9	4	2	Q	0.13	73.7	63.4	64.8	64.9	65	59.3	62	66	Q
11/6/2018	10	4	3	Q	0.13	73.7	64.0	64.0	69.9	58	-	-	-	Q
11/6/2018	11	5	1	Q	0.13	73.7	62.4	62.4	62.4	-	-	-	-	Q
11/6/2018	12	5	2	Q	0.13	73.7	66.1	68.3	68.3	72	-	58	-	Q
11/6/2018	13	5	3	Q	0.13	73.7	63.3	64.4	67.5	67	56.8	-	62.1	L
11/7/2018	14	6	1	L	0.20	79.7	61.1	60.2	65.5	58	61.3	59	-	L
11/7/2018	15	6	2	L	0.20	79.7	60.9	59.1	67.9	59	57.4	59.4	-	L
11/7/2018	16	6	3	L	0.20	79.7	65.6	63.9	77.8	62	55.8	63.9	68.7	M
11/7/2018	17	7	1	L	0.20	79.7	69.7	68.9	76.9	69	69.4	64.6	68.9	L
11/8/2019	18	8	1	M	0.28	84.0	67.8	67.8	68	68	-	-	-	M
11/8/2019	19	8	2	L	0.20	79.7	68.0	67.0	77.7	70	59.2	66	67	H
11/8/2019	20	9	1	L	0.20	79.7	65.7	66.8	69.6	65	59.7	-	68.3	M
11/8/2019	21	9	2	M	0.28	84.0	68.3	68.3	79.3	68	57.1	69	67.8	H

Date	Thump #	QSF18 Flight	Pass	Design (Alpha)			Measured (other)								Flown to Level
				Level [1]	Target PSF (max)	Target PLdB (max)	Measured PLdB (average)	Measured PLdB (median)	Foxtrot	Golf	Hotel	India	Juliet	
11/10/2018	22	10	1	M	0.28	84.0	66.8	67.1	75	67	58.2	-	-	M
11/10/2018	23	10	2	L	0.20	79.7	49.1	64.2	0	68	63.9	-	64.4	M
11/10/2018	24	11	1	L	0.20	79.7	64.7	65.8	67	66	61.3	-	-	M
11/10/2018	25	11	2	M	0.28	84.0	66.1	68.8	71.5	69	61.1	68.8	60.5	MH
11/10/2018	26	11	3	M	0.28	84.0	74.5	72.6	86.8	67	69.6	72.6	75.9	H
11/10/2018	27	12	1	M	0.28	84.0	70.8	72.4	75.4	73	63.8	69.2	72.4	H
11/10/2018	28	12	2	M	0.28	84.0	66.5	63.9	74.6	69	61.8	63.9	63	MH
11/11/2018	29	13	1	L	0.20	79.7			-	-	-	-	-	L
11/11/2018	30	13	2	M	0.28	84.0	66.4	66.4	72.3	-	60.5	-	-	MH
11/11/2018	31	14	1	M	0.28	84.0	70.3	70.3	70.3	-	-	-	-	MH
11/11/2018	32	14	2	L	0.20	79.7	67.8	68.8	72.4	69	62.3	-	-	MH
11/11/2018	33	15	1	M	0.28	84.0	65.6	65.6	74.6	-	56.5	-	-	MH
11/11/2018	34	15	2	M	0.28	84.0	64.7	65.1	69.3	65	-	64.9	59.1	MH
11/13/2018	35	16	1	M	0.28	84.0	70.6	68.0	85.2	68	-	-	58.6	M
11/13/2018	36	16	2	H	0.53	93.3	71.8	72.3	75.6	72	71.3	72.5	67.3	H
11/13/2018	37	16	3	H	0.53	93.3	73.4	69.7	78	69	82.9	69.7	67.3	H
11/13/2018	38	17	1	M	0.28	84.0			-	-	-	-	-	M
11/13/2018	39	17	2	H	0.53	93.3	67.1	68.3	70.5	70	61.4	65.7	68.3	MH
11/14/2018	40	18	1	M	0.28	84.0	64.0	61.7	67	70	61.5	61.7	59.7	M
11/14/2018	41	18	2	L	0.20	79.7	63.0	64.0	67.2	65	-	63.1	57	M
11/14/2018	42	18	3	M	0.28	84.0	65.8	68.5	68.9	69	59.8	69.5	62.2	MH
11/14/2018	43	19	1	L	0.20	79.7	60.0	58.7	59.6	58	66.2	57.6	58.7	L
11/14/2018	44	19	2	L	0.20	79.7	58.0	58.4	58.1	61	58.4	59.8	53.2	L
11/14/2018	45	20	1	L	0.20	79.7	61.6	60.2	66	58	66.6	56.6	60.2	L

Date	Thump #	QSF18 Flight	Pass	Design (Alpha)			Measured (other)							Flown to Level
				Level [1]	Target PSF (max)	Target PLdB (max)	Measured PLdB (average)	Measured PLdB (median)	Foxtrot	Golf	Hotel	India	Juliet	
11/14/2018	46	20	2	L	0.20	79.7	62.8	63.1	65.3	-	59.6	61.3	64.9	M
11/14/2018	47	20	3	L	0.20	79.7	60.6	60.6	60	61	-	-	-	M
11/15/2018	48	21	1	L	0.20	79.7	62.2	60.7	66.4	57	60.7	67.8	59.2	L
11/15/2018	49	21	2	L	0.20	79.7	61.9	61.4	68	56	-	-	61.4	L
11/15/2018	50	21	3	L	0.20	79.7	59.3	57.5	67.4	56	54.9	-	58.5	L
11/15/2018	51	22	1	L	0.20	79.7	59.6	59.6	63.9	55	-	-	-	L
11/15/2018	52	22	2	L	0.20	79.7	69.0	66.8	80.4	69	-	64.7	62	M

Note 1 - Level: Q < =73.7, 73.7<L<=79.7, 79.7<M<=84.0, 84.0<H]

Note 2 - Flight 1 Pass 1 thump only detected at Bravo, not included in analysis

Table T-3 Target thump levels compared to measurements – Max PSF at sensors on Galveston Island

Date	Thump #	QSF18 Flight	Pass	Design			Measured (Galveston Island)										Flown to Level
				Level [1]	Target PSF (max)	Target PLdB (max)	Actual Level [1] (based on median)	Measured PSF (max) (average)	Measured PSF (max) (median)	Alpha	Bravo	Charlie	Delta	Echo	Kilo		
11/5/2018	1	1	1	L	0.20	79.7	[2]			-	0.19	-	-	-	-		Q
11/5/2018	2	1	2	Q	0.13	73.7	L	0.1	0.1	0.14	0.17	0.14	0.18	0.07	0.1		L
11/5/2018	3	1	3	Q	0.13	73.7	L	0.2	0.2	0.14	0.23	0.18	0.14	0.11	0.3		L
11/5/2018	4	2	1	L	0.20	79.7	Q	0.1	0.1	0.1	0.09	0.06	0.08	-	0.1		L
11/5/2018	5	2	2	Q	0.13	73.7	Q	0.1	0.1	0.09	0.15	0.08	0.09	0.07	0.2		L
11/5/2018	6	3	1	L	0.20	79.7	Q	0.1	0.1	0.08	0.29	0.12	0.09	0.13	0.1		L
11/5/2018	7	3	2	Q	0.13	73.7	Q	0.1	0.1	0.1	0.16	0.09	0.07	0.04	0.2		L

Date	Thump #	QSF18 Flight	Pass	Design			Measured (Galveston Island)									Flown to Level
				Level [1]	Target PSF (max)	Target PLdB (max)	Actual Level [1] (based on median)	Measured PSF (max) (average)	Measured PSF (max) (median)	Alpha	Bravo	Charlie	Delta	Echo	Kilo	
11/6/2018	8	4	1	Q	0.13	73.7	L	0.1	0.1	0.16	0.18	0.14	0.13	0.11	0.1	U
11/6/2018	9	4	2	Q	0.13	73.7	L	0.1	0.1	0.12	0.2	0.15	0.15	0.09	0.1	Q
11/6/2018	10	4	3	Q	0.13	73.7	Q	0.1	0.1	0.11	0.16	0.11	0.11	0.08	0.1	Q
11/6/2018	11	5	1	Q	0.13	73.7	Q	0.1	0.1	0.11	0.15	0.12	0.12	0.07	0.1	Q
11/6/2018	12	5	2	Q	0.13	73.7	Q	0.1	0.1	0.11	0.11	0.11	0.12	0.07	0.1	Q
11/6/2018	13	5	3	Q	0.13	73.7	Q	0.1	0.1	0.2	0.15	0.17	0.06	0.08	0	L
11/7/2018	14	6	1	L	0.20	79.7	Q	0.2	0.1	0.11	0.3	0.13	0.12	0.1	0.3	L
11/7/2018	15	6	2	L	0.20	79.7	Q	0.1	0.1	0.07	0.08	0.08	0.08	0.03	0	L
11/7/2018	16	6	3	L	0.20	79.7	M	0.3	0.3	0.23	0.24	0.22	0.4	0.26	0.3	M
11/7/2018	17	7	1	L	0.20	79.7	L	0.2	0.2	0.2	0.36	0.18	0.14	0.12	0.1	L
11/8/2019	18	8	1	M	0.28	84.0	Q	0.1	0.1	0.17	0.11	0.11	0.15	0.08	0.2	M
11/8/2019	19	8	2	L	0.20	79.7	H	0.3	0.3	0.24	0.19	0.27	0.3	0.34	0.4	H
11/8/2019	20	9	1	L	0.20	79.7	L	0.2	0.2	0.22	0.21	0.16	0.21	0.17	0.2	M
11/8/2019	21	9	2	M	0.28	84.0	H	0.4	0.4	0.39	0.24	0.38	0.48	0.37	0.4	H
11/10/2018	22	10	1	M	0.28	84.0	L	0.2	0.2	0.2	0.13	0.15	0.11	0.22	0.2	M
11/10/2018	23	10	2	L	0.20	79.7	L	0.2	0.2	0.17	0.14	0.17	0.24	0.22	0.2	M
11/10/2018	24	11	1	L	0.20	79.7	Q	0.1	0.1	0.11	0.13	0.14	-	0.11	0.1	M
11/10/2018	25	11	2	M	0.28	84.0	L	0.2	0.2	0.23	0.19	0.16	0.09	0.13	0.2	MH
11/10/2018	26	11	3	M	0.28	84.0	H	0.4	0.4	0.34	0.36	0.53	0.45	0.55	0.3	H
11/10/2018	27	12	1	M	0.28	84.0	H	0.4	0.4	0.36	0.45	0.53	0.48	0.4	0.4	H
11/10/2018	28	12	2	M	0.28	84.0	H	0.3	0.3	0.39	0.22	0.26	0.35	0.47	0.2	MH
11/11/2018	29	13	1	L	0.20	79.7	Q	0.0	0.0	-	-	0.02	-	-	0	L
11/11/2018	30	13	2	M	0.28	84.0	M	0.2	0.2	0.19	0.23	0.34	0.23	0.13	0.2	MH
11/11/2018	31	14	1	M	0.28	84.0	M	0.3	0.2	0.17	0.22	0.23	0.2	0.43	0.5	MH

Date	Thump #	QSF18 Flight	Pass	Design			Measured (Galveston Island)									Flown to Level
				Level [1]	Target PSF (max)	Target PLdB (max)	Actual Level [1] (based on median)	Measured PSF (max) (average)	Measured PSF (max) (median)	Alpha	Bravo	Charlie	Delta	Echo	Kilo	
11/11/2018	32	14	2	L	0.20	79.7	Q	0.1	0.1	0.13	0.07	0.08	0.2	0.1	0.1	MH
11/11/2018	33	15	1	M	0.28	84.0	M	0.2	0.2	0.29	0.16	0.28	0.25	0.13	0.2	MH
11/11/2018	34	15	2	M	0.28	84.0	Q	0.1	0.1	0.17	-	0.12	0.13	0.12	0.2	MH
11/13/2018	35	16	1	M	0.28	84.0	H	0.3	0.3	0.37	-	0.3	0.2	0.37	0.2	M
11/13/2018	36	16	2	H	0.53	93.3	H	0.4	0.4	0.26	0.45	0.44	0.6	0.33	0.5	H
11/13/2018	37	16	3	H	0.53	93.3	H	0.3	0.3	0.5	0.18	0.17	0.28	0.5	0.4	H
11/13/2018	38	17	1	M	0.28	84.0	Q	0.1	0.1	0.23	0.06	0.17	0.09	0.11	0.1	M
11/13/2018	39	17	2	H	0.53	93.3	L	0.2	0.2	0.19	0.25	0.2	0.15	-	0.3	MH
11/14/2018	40	18	1	M	0.28	84.0	H	0.3	0.3	0.39	0.56	0.32	0.07	0.09	-	M
11/14/2018	41	18	2	L	0.20	79.7	H	0.4	0.3	0.47	0.57	0.3	0.2	0.32	-	M
11/14/2018	42	18	3	M	0.28	84.0	H	0.5	0.4	0.49	0.4	0.44	0.64	0.41	0.4	MH
11/14/2018	43	19	1	L	0.20	79.7	Q	0.1	0.1	0.16	0.27	0.11	0.04	0.08	0	L
11/14/2018	44	19	2	L	0.20	79.7	Q	0.1	0.0	0.13	0.05	0.08	0.03	0.03	0	L
11/14/2018	45	20	1	L	0.20	79.7	Q	0.1	0.1	0.09	0.14	0.05	0.02	0.03	-	L
11/14/2018	46	20	2	L	0.20	79.7	Q	0.1	0.1	0.17	0.25	0.05	-	0.02	-	M
11/14/2018	47	20	3	L	0.20	79.7	Q	0.2	0.1	0.09	0.6	0.03	-	-	-	M
11/15/2018	48	21	1	L	0.20	79.7	L	0.2	0.2	0.26	0.17	0.2	0.27	0.16	0.2	L
11/15/2018	49	21	2	L	0.20	79.7	L	0.2	0.2	0.23	0.17	0.17	0.2	0.14	0.2	L
11/15/2018	50	21	3	L	0.20	79.7	L	0.1	0.1	0.1	0.23	0.13	0.16	0.09	0.2	L
11/15/2018	51	22	1	L	0.20	79.7	L	0.2	0.2	0.18	0.19	0.14	0.25	0.17	0.2	L
11/15/2018	52	22	2	L	0.20	79.7	M	0.2	0.2	0.37	0.24	0.31	0.2	0.17	0.1	M

Note 1 - Level: Q < =0.13, 0.13<L<=0.20, 0.20M<=0.28, 0.28<H]

Note 2 - Flight 1 Pass 1 thump only detected at Bravo, not included in analysis

Table T-4 Target thump levels compared to measurements – Max PSF at sensors other than on Galveston Island

Date	Thump #	QSF18 Flight	Pass	Design (Alpha)			Measured (other)								Flown to Level
				Level [1]	Target PSF (max)	Target PLdB (max)	Measured PSF (max) (average)	Measured PSF (max) (median)	Foxtrot	Golf	Hotel	India	Juliet	
11/5/2018	1	1	1	L	0.20	79.7	[2]		-	-	-	-	-	Q
11/5/2018	2	1	2	Q	0.13	73.7	0.05	0.04	0.12	0.1	0.04	0.02	0.02	L
11/5/2018	3	1	3	Q	0.13	73.7	0.06	0.05	0.08	0	0.05	-	-	L
11/5/2018	4	2	1	L	0.20	79.7	0.04	0.03	0.07	0	0.02	-	-	L
11/5/2018	5	2	2	Q	0.13	73.7	0.05	0.05	0.07	0	0.05	0.05	-	L
11/5/2018	6	3	1	L	0.20	79.7	0.09	0.09	0.09	-	-	-	-	L
11/5/2018	7	3	2	Q	0.13	73.7	0.08	0.08	0.08	-	-	-	-	L
11/6/2018	8	4	1	Q	0.13	73.7	0.04	0.02	0.07	0.1	0.02	0.02	0.01	U
11/6/2018	9	4	2	Q	0.13	73.7	0.03	0.02	0.06	0	0.02	0.02	0.01	Q
11/6/2018	10	4	3	Q	0.13	73.7	0.04	0.04	0.05	0	-	-	-	Q
11/6/2018	11	5	1	Q	0.13	73.7	0.05	0.05	0.05	-	-	-	-	Q
11/6/2018	12	5	2	Q	0.13	73.7	0.02	0.03	0.03	0	-	0.01	-	Q
11/6/2018	13	5	3	Q	0.13	73.7	0.04	0.03	0.08	0	0.01	-	0.01	L
11/7/2018	14	6	1	L	0.20	79.7	0.04	0.04	0.06	0	0.04	0.02	-	L
11/7/2018	15	6	2	L	0.20	79.7	0.04	0.04	0.06	0.1	0.02	0.03	-	L
11/7/2018	16	6	3	L	0.20	79.7	0.07	0.05	0.17	0.1	0.05	0.03	0.02	M
11/7/2018	17	7	1	L	0.20	79.7	0.06	0.03	0.17	0.1	0.03	0.03	0.02	L
11/8/2019	18	8	1	M	0.28	84.0	0.06	0.06	0.06	0.1	-	-	-	M
11/8/2019	19	8	2	L	0.20	79.7	0.10	0.07	0.26	0.1	0.02	0.05	0.07	H
11/8/2019	20	9	1	L	0.20	79.7	0.04	0.02	0.1	0.1	0.01	0	0.02	M
11/8/2019	21	9	2	M	0.28	84.0	0.13	0.10	0.35	0.1	0.05	0.1	0.06	H

Date	Thump #	QSF18 Flight	Pass	Design (Alpha)			Measured (other)							Flown to Level
				Level [1]	Target PSF (max)	Target PLdB (max)	Measured PSF (max) (average)	Measured PSF (max) (median)	Foxtrot	Golf	Hotel	India	Juliet	
11/10/2018	22	10	1	M	0.28	84.0	0.09	0.07	0.14	0.1	0.05	-	-	M
11/10/2018	23	10	2	L	0.20	79.7	0.04	0.04	-	0	0.04	-	0.03	M
11/10/2018	24	11	1	L	0.20	79.7	0.04	0.05	0.05	0.1	0.03	-	-	M
11/10/2018	25	11	2	M	0.28	84.0	0.07	0.04	0.15	0.1	0.02	0.04	0.03	MH
11/10/2018	26	11	3	M	0.28	84.0	0.22	0.17	0.46	0.1	0.15	0.18	0.17	H
11/10/2018	27	12	1	M	0.28	84.0	0.14	0.13	0.23	0.2	0.08	0.13	0.13	H
11/10/2018	28	12	2	M	0.28	84.0	0.10	0.07	0.23	0.1	0.07	0.06	0.03	MH
11/11/2018	29	13	1	L	0.20	79.7			-	-	-	-	-	L
11/11/2018	30	13	2	M	0.28	84.0	0.05	0.05	0.09	-	0.01	-	-	MH
11/11/2018	31	14	1	M	0.28	84.0	0.08	0.08	0.08	-	-	-	-	MH
11/11/2018	32	14	2	L	0.20	79.7	0.05	0.02	0.11	0	0.01	-	-	MH
11/11/2018	33	15	1	M	0.28	84.0	0.09	0.09	0.17	-	0.01	-	-	MH
11/11/2018	34	15	2	M	0.28	84.0	0.04	0.04	0.07	0.1	-	0.02	0.01	MH
11/13/2018	35	16	1	M	0.28	84.0	0.24	0.11	0.59	0.1	-	-	0.03	M
11/13/2018	36	16	2	H	0.53	93.3	0.22	0.21	0.33	0.2	0.2	0.26	0.12	H
11/13/2018	37	16	3	H	0.53	93.3	0.29	0.16	0.35	0.2	0.68	0.15	0.11	H
11/13/2018	38	17	1	M	0.28	84.0			-	-	-	-	-	M
11/13/2018	39	17	2	H	0.53	93.3	0.10	0.08	0.17	0.1	0.08	0.07	0.07	MH
11/14/2018	40	18	1	M	0.28	84.0	0.09	0.06	0.2	0	0.06	0.06	0.07	M
11/14/2018	41	18	2	L	0.20	79.7	0.11	0.10	0.18	0.1	-	0.07	0.07	M
11/14/2018	42	18	3	M	0.28	84.0	0.17	0.15	0.3	0.2	0.13	0.15	0.06	MH
11/14/2018	43	19	1	L	0.20	79.7	0.06	0.04	0.1	0.1	0.03	0.04	0.01	L
11/14/2018	44	19	2	L	0.20	79.7	0.05	0.05	0.09	0	0.02	0.05	0.05	L
11/14/2018	45	20	1	L	0.20	79.7	0.04	0.04	0.05	0	0.04	0.02	0.04	L

Date	Thump #	QSF18 Flight	Pass	Design (Alpha)			Measured (other)								Flown to Level
				Level [1]	Target PSF (max)	Target PLdB (max)	Measured PSF (max) (average)	Measured PSF (max) (median)	Foxtrot	Golf	Hotel	India	Juliet	
11/14/2018	46	20	2	L	0.20	79.7	0.09	0.10	0.13	-	0.04	0.1	0.09	M
11/14/2018	47	20	3	L	0.20	79.7	0.02	0.02	0.02	0	-	-	-	M
11/15/2018	48	21	1	L	0.20	79.7	0.03	0.02	0.08	0	0.02	0.02	0.01	L
11/15/2018	49	21	2	L	0.20	79.7	0.04	0.02	0.08	0	-	-	0.01	L
11/15/2018	50	21	3	L	0.20	79.7	0.03	0.02	0.09	0	0.01	-	0.01	L
11/15/2018	51	22	1	L	0.20	79.7	0.05	0.05	0.07	0	-	-	-	L
11/15/2018	52	22	2	L	0.20	79.7	0.08	0.03	0.23	0	-	0.02	0.02	M

Note 1 - Level: Q < =73.7, 73.7<L<=79.7, 79.7<M<=84.0, 84.0<H]

Note 2 - Flight 1 Pass 1 thump only detected at Bravo, not included in analysis

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14. ABSTRACT
The Quiet Supersonic Flights 2018 (QSF18) Program was designed to develop tools and methods for demonstration of overland supersonic flight with an acceptable sonic boom, and collect a large dataset of responses from a representative sample of the population. Phase 1 provided the basis for a low amplitude sonic boom testing in six different climate regions that will enable international regulatory agencies to draft a noise-based standard for certifying civilian supersonic overland flight. Phase 2 successfully executed a large scale test in Galveston, Texas, developed well documented data sets, calculated dose response relationships, yielded lessons, and identified future risk reduction activities.

15. SUBJECT TERMS
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